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Ecological Survey Data for Environmental Considerations on the Trinity River and Tributaries, Texas

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STEPHEN F. AUSTIN STATE UNIVERSITY
NACOGDOCHES, TEXAS

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The general objective of the study was to provide a base of scientific data to be used in evaluating the ecological significance of future water development plans on the Trinity River. The specific objectives were: (1) to determine the degree of existing eutrophication and water pollution; (2) to study ecological factors influencing the distribution and abundance of fishes, birds, and mammals; (3) to describe and analyse representative plant communities; (4) to describe and analyze terrestrial and aquatic macroinvertebrate

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20. communities; (5) to locate geological structures of ecological and economic significance and to analyze their present and potential effects on biotic communities; (6) to analyze certain lignite deposits for heavy metals and sulfur and analyze their potential effects on biotic communities.

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Ecological Survey Data for Environmental Considerations on the Trinity River and Tributaries, Texas

STEPHEN F. AUSTIN STATE UNIVERSITY
NACOGDOCHES, TEXAS

(6) ECOLOGICAL SURVEY DATA FOR ENVIRONMENTAL CONSIDERATIONS ON THE TRINITY RIVER AND TRIBUTARIES, TEXAS.

by

(10) Charles D./Fisher
Darrell D./Hall
Hershel L./Jones
Jack D./McCullough
Elray S./Nixon

Jack E. Coster, Project Director

(9) Preliminary rept.

Stephen F. Austin State University
Nacogdoches, Texas

Prepared For

U. S. Army Corps of Engineers
Fort Worth District
Fort Worth, Texas

15

In Accordance with Contract No. DACW 63-73-C-0016

PRELIMINARY

This report does not necessarily constitute the final project concept to be adopted by the U.S. Army Corps of Engineers.

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To the many landowners along the Trinity River who permitted access to the river, the study team extends their thanks. The Fin and Feather Club near Dallas was most gracious in connection with bird, mammal, and plant aspects of the study.

Mrs. Susan Florence performed all of the typing, key-punching, and assembling of the report. Her patience and hard work are greatly appreciated.

***

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CHAPTER I

INTRODUCTION

by

Jack E. Coster
Project Leader

INTRODUCTION

In September, 1971 Stephen F. Austin State University began a project to survey the environmental and cultural impact of water resource development activities proposed for the Trinity River by the U.S. Army Engineers. The initial study, performed through U.S. Army contract DACW 63-72-0005, consisted of two phases: the first phase was a survey of the site of the proposed Tennessee Colony Reservoir and the second phase was a survey of the remainder of the river from Fort Worth to the headwaters of the proposed Wallisville Lake below Liberty. The final report of the first phase ("Environmental and cultural impact of the proposed Tennessee Colony Reservoir, Trinity River, Texas", 5 vols.) Was submitted to the Army Engineers on January 31, 1972. The final report for phase two of the initial study ("A survey of the environmental and cultural resources of the Trinity River", 398 pp) was submitted on September 1, 1972.

The environmental and cultural surveys indicated the need for in-depth studies in order to provide more complete data for water development plans on the river. On September 1,1972 Stephen F. Austin State University began in-depth ecological studies under the terms of U.S. Army contract DACW 63-73-C-0016. The general objective of the study was to provide a base of scientific data to be used in evaluating the ecological significance of future water development plans on the Trinity River. To accomplish this general goal, the following specific objectives were set forth:

1. To determine the degree of existing eutrophication and water pollution.

2. To study ecological factors influencing the distribution and abundance of fishes, birds, and mammals.

3. To describe and analyze representative plant communities.

4. To describe and analyze terrestrial and aquatic macroinvertebrate communities.

5. To locate geological structures of ecological and economic significance and to analyze their present and potential effects on biotic communities.

6. To analyze certain lignite deposits for heavy metals and sulfur and analyze their potential effects on biotic communities.

The Trinity River Basin is easily delineated from its surrounding land areas and, at any given time, is occupied by a particular grouping of plants and animals. It is, therefore, an ecosystem in the classical sense. An ecosystem as large and diverse as the Trinity River Basin is extremely difficult to study, even for only a few parameters. Field ecology studies are costly, placing further restraints on ecosystem sampling. If, however, the biological and geological operations of a river are observed at a variety of carefully selected, typical cross-sections of the stream a total picture of the ecosystem may result. Such an approach has the additional advantage of serving as a monitor of biological and chemical conditions of the river when carried out over a long period of time.

Using the "cross-section" approach, 10 study areas were selected. Criteria for establishing the study areas were: (1) type of plant covers; (2) proximity to major sources of water pollution; (3) type of existing land use patterns; (4) nearness to major geological structures or geological deposits of economic value; (5) location of proposed Corps projects (channel alignment, reservoirs, and locks); (6) presence of known fish and bird breeding grounds; (7) and general accessibility.

Beginning at the uppermost study area and proceeding south they are described briefly as follows (see enclosed maps):

1. Between Fort Worth and Dallas, west of the highway 360 crossing.

2. South of Dallas near Loop 12 crossing.

3. West of Rosser at confluence of Trinity and old channel of the East Fork.

4. Northeast of Kerens at the large horseshoe bend at the Bruce Smith Ranch in Henderson County (in Tennessee Colony Reservoir Site).

5. South of Highway 287 at Richland Creek (in Tennessee Colony Reservoir Site).

6. Southwest of Palestine, north of Highway 79 crossing.

7. Northeast of Madisonville, southeast of Highway 21 crossing.

8. Between Livingston Dam and Highway 59 crossing.

9. Northwest of Moss Hill, at Tanner Bayou.

10. North of Wallisville, at Chambers-Liberty county line.

This report presents the results of the investigation carried out between September 1, 1972 and June 30, 1973.

CHAPTER II

BOTANICAL ELEMENTS

by

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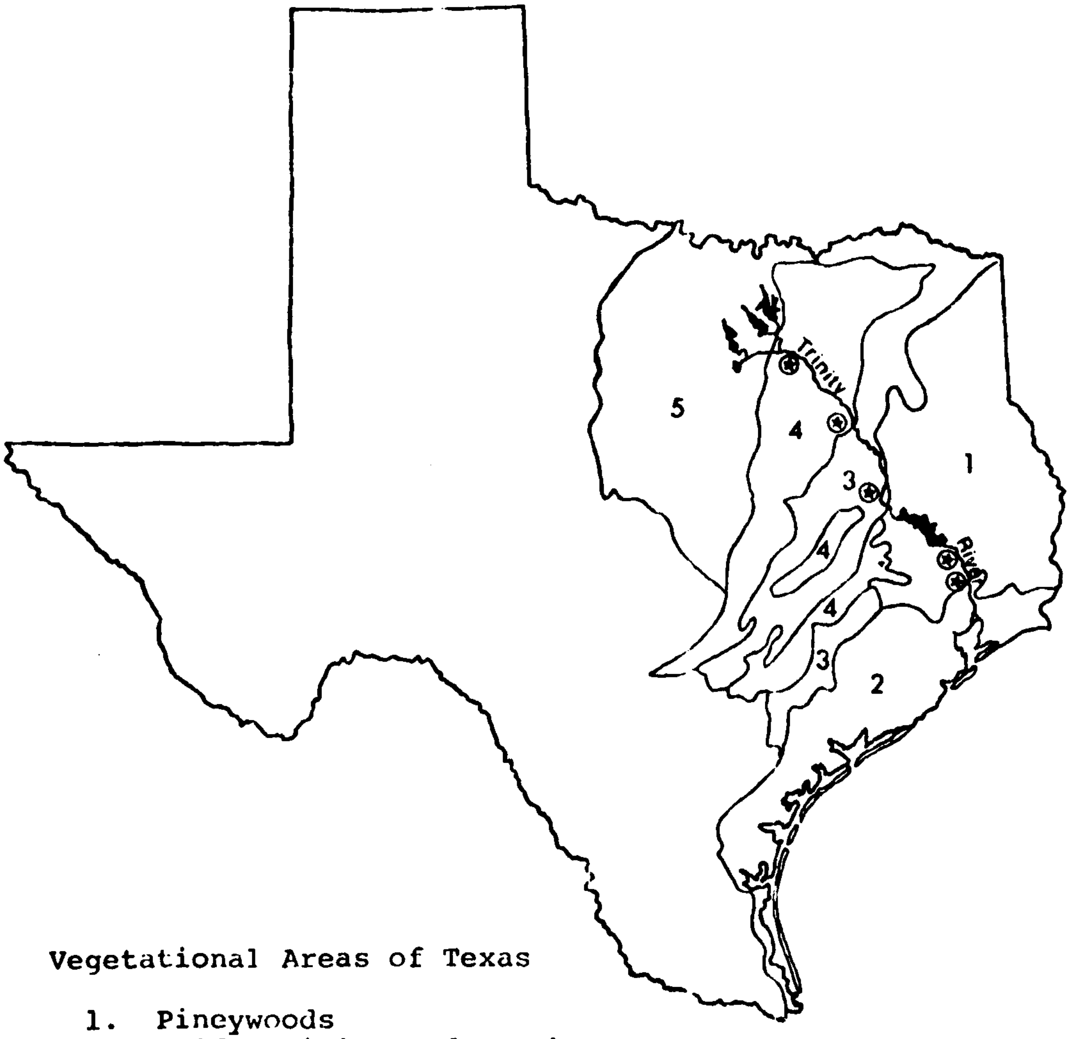
INTRODUCTION

Vegetatively, the Trinity River Basin is associated with several areas or types. Gould (1969) divides Texas into ten vegetational areas . The Trinity River transects the Pineywoods, Gulf Prairies and Marshes, Post Oak Savannah, Blackland Prairies and Cross Timbers and Prairies vegetational areas (Fig. II-01). Following are brief descriptions of these areas as generally characterized by Gould (1969).

The Trinity River, within the confines of this study, transects only a small portion of the Cross Timbers and Prairies area. The area is very variable from the standpoints of rainfall,soils and land use. The vegetation, however, is generally rather uniform. Predominant native grasses in the prairies are little bluestem (Schizachyrium scoparium), big bluestem (Andropogon gerardi), Indiangrass (Sorghastrum avenaceum), switchgrass (Panicum virgatum) and Canada wild-rye (Elymus canadensis). The Cross Timbers areas are dominated by trees such as post oak (Quercus stellata) and blackjack oak (Quercus marilandica) with herbaceous understory species including hairy tridens (Erioneuron pilosum) and Texas grama (Bouteloua rigidiseta). The Blackland Prairies, under natural conditions, would be dominated by grasses such as little bluestem, big bluestem, switchgrass, Indiangrass and sideoats grama (Bouteloua curtipendula). The soils are generally dark-colored calcareous clays.

In general, the Post Oak Savannah vegetational area is characterized by the presence of upland trees such as post oak, blackjack oak and sandjack oak (Quercus incana) and of marginal bottomland species including southern red oak (Quercus falcata), white oak (Quercus alba), hickory (Carya spp.) and elm (Ulmus spp.) (Bray, 1906). The upland soils of the Post Oak Savannah area are light colored, generally acid and are texturally classed as either sands or sandy loams. Bottomland soils are darker in color, acid, and range from sandy loams to clays.

The Pineywoods vegetation area is depicted by trees such as shortleaf pine (Pinus echinata), loblolly pine (Pinus taeda), post oak, blackjack oak, red oak, sweetgum (Liquidambar styraciflua) and black hickory (Carya texana) in the uplands and by overcup oak (Quercus lyrata), willow oak (Quercus Phellos), Texas sugarberry (Celtis laevigata), cedar elm (Ulmus crassifolia) and bush palmetto (Sabal



Vegetational Areas of Texas

1. Pineywoods
2. Gulf Prairies and Marshes
3. Post Oak Savannah
4. Blackland Prairies
5. Cross Timbers and Prairies

⊛ Study areas

Figure II-1. Map positioning the Trinity River in relation to surrounding vegetational areas. Vegetational areas after Gould, 1969. Study areas are also shown.

minor) in the bottomlands (Tharp, 1926, 1939, 1952; Braun, 1950). The soils are usually light-colored, acid, and sands or sandy-loams.

The climax vegetation of the flat Gulf Prairies and Marshes area is largely grassland or post oak savannah. Tall bunch grasses such as big bluestem, Indiangrass, eastern gamagrass (*Tripsacum dactyloides*) and gulf muhly *Muhlenbergia capillaris* var. *filipes*) are characteristic. Soils are generally acid sands, sandy loams and clays.

Although the Trinity River is associated with the above vegetational areas, the vegetation type of great concern in this study was that of bottomland hardwood forests. Bottomland forests associated with the Sabine, Neches, Trinity, and San Jacinto river systems occupy large areas and, as a result, have been classified by Bray (1906) and Collier (1964) as distinct vegetational types. These bottomland forests are considered to be westward extensions of hardwood forests typical of river bottom areas to the southeast (Bray, 1906; Braun, 1950).

OBJECTIVES

The major objectives of this study were to describe and analyze representative plant communities in association with the Trinity River Basin in Texas. In addition, notes on rare, endemic or endangered species were to be made.

METHODS AND PROCEDURES

The scope of the botanical studies is limited to community analyses in five of the previously described study areas. We studied areas 2, 5, 7, 8, and 9. The approximate geographical locations of the botanical study areas are shown in Figure II-01.

Quantitative data were acquired for woody shrubs and trees with diameters at breast height (dbh) greater than 1/2 cm whereas vine and herbaceous plants were collected, identified, and incorporated in a checklist. The woody vegetation of all areas was analyzed by the plot method. Each plot was $5m^2$ and situated in a belt transect. Each belt transect , in turn, was composed of two rows of plots following a compass line. Transects were generally 250 meters in length and composed of 100 plots. Woody species in each plot were identified, measured (dbh) and counted. From this data, frequency, density, dominance and importance value figures were obtained. Dominance,

therefore, is based upon importance value (importance value is equal to the sum of relative frequency, relative density and relative dominance) when used in this study. Nomenclature for plant species followed Correll and Johnston (1970).

STUDY AREA 2

Introduction

Study Area 2 was situated in the floodplain of the Trinity River in the southeast corner of Dallas County. More specifically it was located southeast of the junction of Interstate Highways 45 and 635 in the vicinity of the Pin and Feather Club and Dallas Hunting and Fishing Club lakes. Field analyses were accomplished during the spring of 1973.

Topography of the immediate study sites was generally flat with occasional depressions and small creeks. Geologically the area is composed of Alluvium deposits of Recent origin within the Quaternary Period. Indistinct low terrace deposits may also be included. Soils in Study Area 2 are comprised of Trinity Clay. This soil type is poorly suited for dwellings, septic tanks, streets, light industry, and camp areas and most other recreational use (U.S. Department of Agriculture, Soil Conservation Service, 1972).

The study sites were forested whereas surrounding areas were generally cleared for pasture, housing and gravel pit usage. Grazing by cattle was evident in one study site and it is likely that the other study sites have been used for domestic grazing in the past.

Land Use

Dallas County, in which is situated the State's second largest metropolitan center, had a population in 1970 of 1,327,321, up sharply from 951,527 in 1960 (Texas Almanac, 1971). Forty-eight percent of the county's total area is classified urban and built-up (Table II-01) (Dallas County Conservation Needs Inventory Committee, 1970). While slightly over half of the total area is farm and forest land, its contribution to the income of the county is comparatively small--about $11 million annually out of a total income in excess of $5 billion.

Between 1958 and 1967, over 43,000 acres were put into urban development (Table II-01) (Dallas County Conservation

Table II-01. Dallas County land area (in acres)
(from Dallas County Conservation Needs Inventory Committee, 1970.)

Land Use	1958	1967
Total land area	552,040	552,040
Less: Federal non-cropland	1,307	1,223
Less: Urban and built-up	221,398	264,637
Less: Small water areas	528	580
Total non-commerical area	223,233*	266,440
Total commercial farm and forest area	347,687*	285,600
Cropland	198,394	138,232
Pasture	37,451	96,273
Range**	60,291	28,594
Forest**	42,614	7,613
Other land	8,937	14,888

* The failure of these two figures to add up to total area is due to discrepancies in original data.

** Part of decrease in rangeland and (especially) forest land acreages is due to difference in interpretation of land uses in 1958.

Needs Inventory Committee, 1970). Over 60,000 acres were taken out of row crop cultivation during this time, and pastureland increased by nearly 59,000 acres. Rangeland decreased by nearly 12,000 acres and forest land by almost 35,000 acres. "Other lands", including farmsteads and rural land for residences, increased nearly 6,000 acres.

An appraisal of potential for outdoor recreational developments in Dallas County (Anonymous, 1967a) stated that the large population of the county causes potential to be high for some outdoor recreational enterprises. At the same time, however, the dense population and urban build-up adversly affect other enterprises which depend to a great extent on the natural environment. A high potential was judged to exist for play and target areas, bicycling, picnicking, golf courses, and riding stables. Fishing and water sports have only medium potential due to the limited lakes and impoundment sites and the already heavy use of existing areas. Medium potential is said to exist for vacation homes, limited mainly by the few available water areas. Overall, Dallas County is a consumer rather than a supplier of outdoor recreation.

Methods and Procedures

Three study sites comprised Study Area 2 (Fig. II-02). The more undisturbed plant communities were selected to represent the woody vegetation of this area. The position of study transects is presented in Figure II-02. A total of 600 plots ($5m^2$) were analyzed with two hundred being located in each study site.

Description of Study Sites

Site 1 was located east of the Trinity River between the river and Dowdy Ferry Road (Fig. II-02). It was a flat, poorly drained site in the vicinity of a small creek. Water stands in much of the area after heavy rains. Site 2 was characterized by a greater habitat diversity as a result of a slightly elevated and better drained area bordering a wet flat. This site was located just east of the junction of Dowdy Ferry Road and the Trinity River (Fig. II-02). The forest has not been logged for many years as a result of its preservation by the Dallas Hunting and Fishing Club. Site 3 was a forest within the Fin and Feather Club area and was located between the northern end of the Fin and Feather Club Lake and the Trinity River (Fig. II-02). The area was flat with occasional, shallow, water-filled depressions. These depressions are probably dry during most of the summer and fall. The area was selectively logged in 1972 resulting in the removal of many large trees.

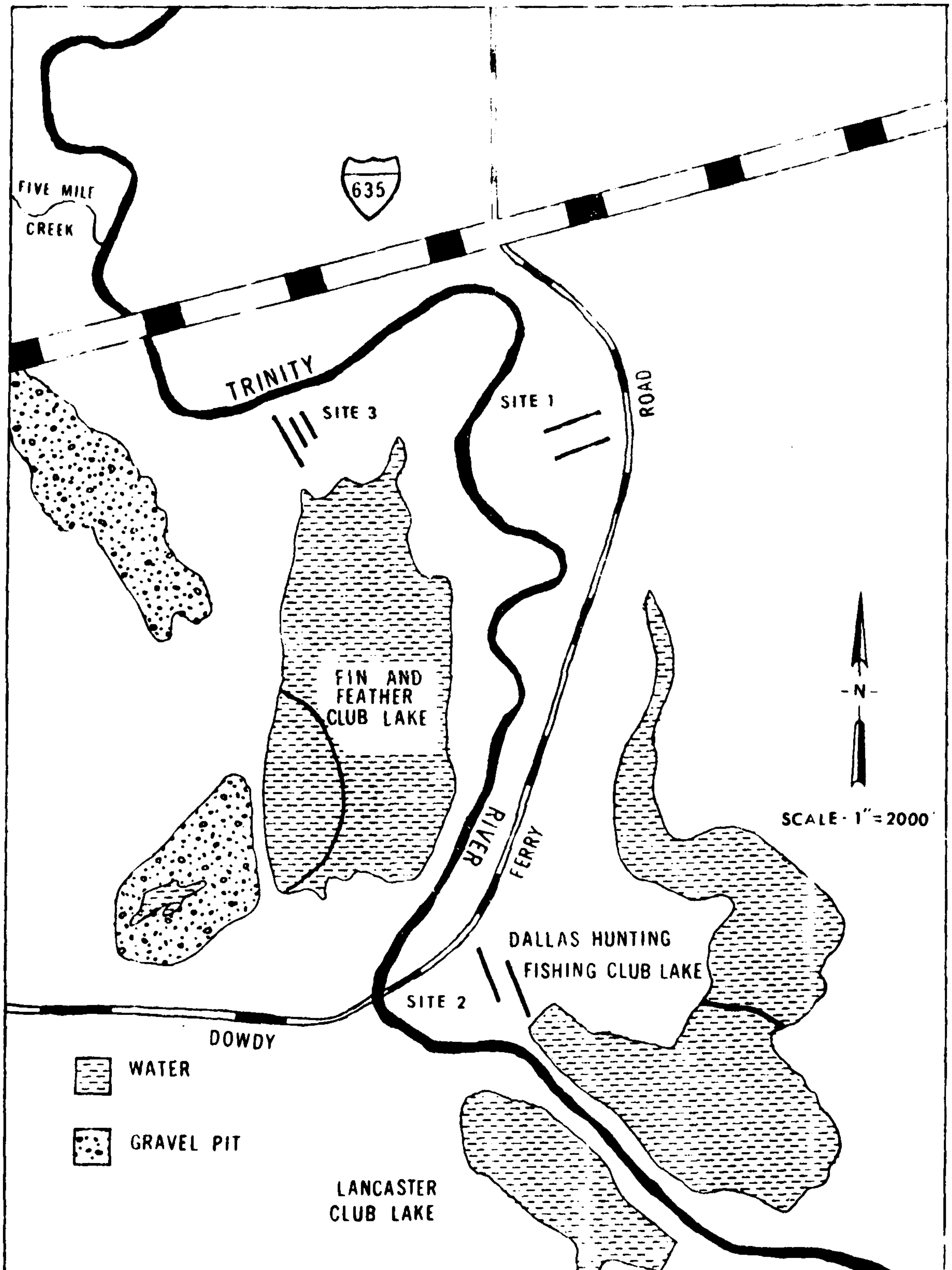


Figure II-02. Showing sites 1,2,and 3 and the position of transects within these sites.

Results

Site 1

The forest comprising Site 1 was rather uniform in species composition with only 10 species being recorded. Texas sugarberry (*Celtis laevigata*), cedar elm (*Ulmus crassifolia*), swamp privet *Forestiera acuminata*) and green ash (*Fraxinus pensylvanica*) were by far the dominant species (Table II-02). Osage orange (*Maclura pomifera*), soapberry (*Sapindus saponaria*) and honey locust were only occasionally observed. Most trees in the area were less than 30 cm in diameter at breast height (Table II-03). Some large cedar elm and green ash trees were present. Except for a few dense populations of cedar elm, the shrub layer was generally open. Empirical observation indicates that the herb layer was composed primarily of sedges (*Carex* spp) with frequently occurring plants of buttercup (*Ranunculus carolinianus*) and crow poison (*Nothoscordum bivalve*).

Site 2

The habitat diversity at Site 2 resulted in a greater species diversity as indicated by the recording of 30 species. Understory vegetational layers were also more dense and diversified. The principal tree species in the area were green ash, cedar elm, deciduous holly (*Ilex decidua*) and roughleaf dogwood (*Cornus Drummondii*) (Table II-04). Shumard red oak (*Quercus Shumardii*), pecan (*Carya illinoinensis*), eastern red cedar (*Juniperus virginiana*) and elm (*Ulmus* spp) were prevalent associated species. Tree diameters were generally less than 50 cm although a few larger trees were recorded (Table II-05).

Site 3

Pecan was the dominant species at Site 3 associated with cedar elm, deciduous holly, Texas sugarberry and roughleaf dogwood (Table II-06). The forest understory was somewhat open and contained a rather uniform herb layer of sedges and violets (*Viola* spp.). Large trees present were mostly pecan (Table II-07). There was a fairly good species diversity at Site 3 with 25 species being recorded.

STUDY AREA 5

Introduction

Study Area 5 was situated on the floodplain of Richland Creek in south-central Navarro County west of the Trinity River. More exactly, it was located south of the

Table II-02. Frequency, density and dominance data for plant species located in Site 1.

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Celtis laevigata	58.0	29.9	3.19	49.4	19.6	98.9
Ulmus crassifolia	47.5	24.5	1.27	19.7	33.6	77.8
Forestiera acuminata	42.5	21.9	1.24	19.2	12.4	53.5
Fraxinus pensylvanica	30.0	15.5	0.48	7.4	24.8	47.7
Maclura pomifera	7.0	3.6	0.09	1.3	8.1	13.0
Sapindus Saponaria	5.0	2.6	0.14	2.2	0.4	5.2
Gleditsia triacanthos	2.0	1.0	0.03	0.5	1.0	2.5
Morus rubra	1.0	0.5	0.01	0.2	0.1	0.8
Ulmus spp.**	0.5	0.3	0.01	0.1	***	0.4
Morus alba	0.5	0.3	0.01	0.1	***	0.4
Total	----	100.1	6.47	100.1	100.0	300.2

* Sum of relative frequency, relative density, and relative dominance.

** May include *Ulmus americana* and *U. rubra*.

*** Value less than 0.1%.

Table II-C3. Size classes (dbh) of plant species located in Site ..

Species	Size Classes (cm)									
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Celtis laevigata	579	42	16							
Ulmus crassifolia	176	53	13	9	2	1				
Forestiera acuminata	218	19	2							
Fraxinus pensylvanica	53	22	17		1	1	1			
Maclura pomifera	4	5	6	2						
Sapindus Saponaria	27	1								
Gleditsia triacanthos	3	2	1							
Morus rubra	1	1								
Ulmus spp.*	1									
Morus alba	1									
Total	1063	145	55	11	3	2	1			

* May include *Ulmus americana* and *U. rubra.*

Table II-04. Frequency, density and dominance data for plant species located in Site 2.

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Fraxinus pensylvanica	29.5	8.3	2.70	26.7	6.3	41.3
Ulmus crassifolia	42.0	11.8	0.83	8.2	16.9	36.9
Ilex decidua	51.5	14.5	1.68	16.6	2.0	33.1
Cornus Drummondii	43.5	12.2	1.98	19.7	0.9	32.8
Quercus Shumardii	6.5	1.8	0.08	0.7	14.1	16.6
Carya illinoinensis	8.5	2.4	0.10	1.0	11.3	14.7
Juniperus virginiana	23.0	6.5	0.34	3.3	3.8	13.6
Ulmus spp.**	9.0	2.5	0.12	1.1	7.5	11.1
Maclura pomifera	8.0	2.3	0.12	1.2	6.0	9.5
Celtis laevigata	17.5	4.9	0.25	2.5	2.0	9.4
Others***		32.8	1.95	18.5	29.2	80.5
Total	----	100.0	10.15	99.5	100.0	299.5

* Sum of relative frequency, relative density, and relative dominance.

** May include *Ulmus americana* and *U. rubra.*

*** Other species present listed in order of decreasing importance values: *Acer negundo*, *Cercis canadensis*, *Populus deltoides*, *Quercus* spp. (includes *Quercus stellata* and *Q similis*), *Fraxinus americana*, *Morus rubra*, *Quercus macrocarpa*, *Sapindus Saponaria*, *Ulmus alata*, *Callicarpa americana*, *Diospyros virginiana*, *Viburnum rufidulum*, Carya texana, *Bumelia lanuginosa*, Gleditsia triacanthos, *Amorpha fruticosa*, *Prunus mexicana*, *Vitex agnus-castus*, *Zanthoxylum clava-herculis*, *Rhamnus lanceolata*.

Table II-05. Size classes (dbh) of plant species located in Site 2.

Species	Size Classes (cm) 1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Fraxinus pensylvanica	531		4	2	2					
Ulmus crassifolia	107	40	15	3	1					
Ilex decidua	335									
Cornus Drummondii	397									
Quercus Shumardii	1		4	4	5		1			
[illegible] illinoensis		1	13	6						
Juniperus virginiana	54	9	3							
Ulmus spp.*	9	7	2	3	1	1				
Maclura pomifera	12	7	3	1		1				
Celtis laevigata	41	7	2							
Others**	336	19	12	7	2	2	1		1	
Total	1823	90	58	26	12	4	2		1	

* May include Ulmus americana and U. rubra.

** See Table II-04 for a list of other species present.

Table II-06. Frequency, density and dominance data for plant species located in Site 3.

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Carya illinoinensis	34.0	9.6	0.40	6.4	38.3	54.3
Ulmus crassifolia	43.0	12.2	0.67	10.8	15.0	38.0
Ilex decidua	57.0	16.1	1.14	18.4	2.4	36.9
Celtis laevigata	48.5	13.7	0.80	12.9	8.5	35.2
Cornus Drummondii	39.0	11.0	1.39	22.4	0.8	34.2
Ulmus spp.**	17.5	5.0	0.18	2.9	6.7	14.6
Quercus macrocarpa	5.5	1.6	0.06	0.9	8.5	11.0
Juniperus virginiana	18.5	5.2	0.23	3.7	1.4	10.3
Fraxinus pensylvanica	12.0	3.4	0.30	4.9	1.7	10.0
Morus rubra	12.5	3.5	0.15	2.3	1.8	7.6
Others***		18.5	0.94	14.3	14.8	47.6
Total	----	99.8	6.26	99.9	100.0	299.7

* Sum of relative frequency, relative density, and relative dominance.

** May include *Ulmus americana* and *U rubra.*

*** Other species present listed in order of decreasing importance values: *Quercus Shumardii*, *Sapindus Saponaria*, *Maclura pomifera*, *Bumelia lanuginosa*, *Acer negundo*, *Fraxinus americana*, *Viburnum rufidulum*, *Prunus mexicana*, *Amorpha fruticosa*, *Diospyros virginiana*, *Gleditsia triacanthos*, *Cercis canadensis*, *Ligustrum spp.*, *Forestiera acuminata*, *Populus deltoides*.

Table II-07. Size classes (dbh) of plant species located in Site 3.

Species	Size Classes (cm)									
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Carya illinoinensis	6	11	36	18	5	3				
Ulmus crassifolia	77	38	13	5	1					
Ilex decidua	227									
Celtis laevigata	107	48	4							
Cornus Drummondii	277									
*Ulmus spp.**	12	18	2	2	2					
Quercus macrocarpa	1	2	1	2	4		1			
Juniperus virginiana	42	2		2						
Fraxinus pensylvanica	52	5	3							
Morus rubra	16	13								
Others**	142	25	9	1	1		1	1		
Total	959	162	68	30	13	3	2	1		

* May include *Ulmus americana* and *U. rubra.*

** See Table II-06 for a list of other species present.

junction of the Chicago, Burlington, Rock Island and Pacific Railroad and Richland Creek at an elevation of about 295 feet above sea level. Field data were collected in the spring of 1973.

The immediate study sites had a flat topography intersected by several smaller creeks and drainages. Geologically, the area was composed of Alluvium deposits of Recent origin within the Quaternary Period. Trinity Clay comprised the soil of the study area. The soil, because of its frequent flooding, is poorly suited for dwellings or intensive recreational use. It is well suited for pond reservoir areas, and has fair suitability for wildlife, woodland and pasture or range (U.S. Department of Agriculture, unpublished data).

The study sites are forested whereas surrounding, more elevated areas have been cleared for pasture. Cattle grazed within the study area.

Land Use

Navarro County had a 1970 population of 31,150, down from the 1960 population of 34,423 (Texas Almanac, 1971). Over half of the county's population (19,972 inhabitants) lived in Corsicana, the largest town and the county seat. Some 4500 more people lived in smaller towns of less than 1,000 inhabitants. The economy of the county is based chiefly on agribusiness, industry, and oil. Of the county's $82,430,000 total income, $14,500,000 was farm income. Eighty percent of this was derived from beef cattle and poultry, while grain sorghums, cotton and hay were the leading crops.

Only about 6% (39,865 acres) of the county's total 695,488 acres were classified as non-commerical (Table II-08) (Navarro County Conservation Needs Committee, 1967). Between 1958 and 1967 about 10,000 acres changed from commercial to the non-commercial classification, chiefly due to the acquisition of about 8500 acres by the Federal government. In this same period, there was an approximately 42% (over 225,000 acres) decline in cropland acreage. Forestland area in this period declined from over 110,000 acres to less than 39,000, a drop of about 71,400 acres or almost 65%. At the same time, the classification "other land" increased by 1200 acres from 2,620 to 3,816 acres. Pasture, however, made striking gains, increasing from a relatively small acreage of 27,199 acres in 1958 to 314,671 acres in 1967, an increase of about 287,500 acres or

Table II-08. Navarro County land area (in acres).
(from Navarro County Conservation Needs Committee, 1967.)

Land Use	1958	1967
Total land area*	693,760	695,488
Less: Federal non-cropland	0	8,492
Less: Urban and built-up	21,873	22,973
Less: Small water areas	7,900	8,400
Total non-commercial area	29,773	39,865
Total commercial farm and forest area	663,987	655,623
Cropland	524,049**	298,545**
Pasture	27,199**	314,671**
Range	8,565**	27,989**
Forest	110,119**	38,591**
Other land	2,620**	3,816**

* The acreage difference in total land area is due to a different system of measuring land use by the Bureau of the Census. Total land area excludes water areas over 40 acres in size.

** The failure of these figures to conform to their respective totals is a result of discrepancies in the original data.

approximately 1157%. Rangeland acreage also increased from 8,565 acres in 1958 to 27,989 by 1967, up some 19,400 acres or about 325%. In 1967, pasture and rangeland together made up about 49% of Navarro County's total land area.

An appraisal of potential for outdoor recreational developments (Anonymous, 1967c) concluded that Navarro County offers moderate attractions to recreation seekers. An asset is the county's location within an hour's drive of both Dallas and Waco. Unfavorable factors include a hot summer climate, the relatively small area of woodland and wildlife habitat, and the heavy clay soils which make off-pavement access almost impossible after heavy rains.

Due to the presence of a number of reservoirs and flood control impoundments, fishing headed the list of potential recreational pursuits with a high medium rating. Medium potential was seen for vacation cabins and homesites, camping grounds, picnicking and field sports, standard and par-3 golf courses, small game hunting, scenic and historic areas, vacation farms, and water sports areas.

Navarro County cannot offer the quality of recreation that draws visitors to Polk, San Jacinto and Liberty counties along the lower Trinity River. According to local residents, however, Dallasites are buying land for vacation homes in Navarro County and land prices have risen noticeably as a result.

Methods and Procedures

Three study sites comprised Study Area 5. The more undisturbed plant communities representing the woody vegetation of the area were selected for analysis. Positions of transects are presented in Figure II-03. A total of 700 plots ($5m^2$) were analyzed, 300 in Site 1 and 200 each in Sites 2 and 3.

Description of Study Sites

All three study sites were located on a flat floodplain subject to occasional overflow. Moving water 1 to 2 feet deep covered the entire Study Area when sampling was begun but receeded within 4 or 5 days. Flooding is controlled to an extent by the Navarro Mills Reservoir on upper Richland Creek. Selective cutting of large trees, mainly bur oak (*Quercus macrocarpa*), for barrel staves about 25 or 30 years ago represents the latest logging operation.

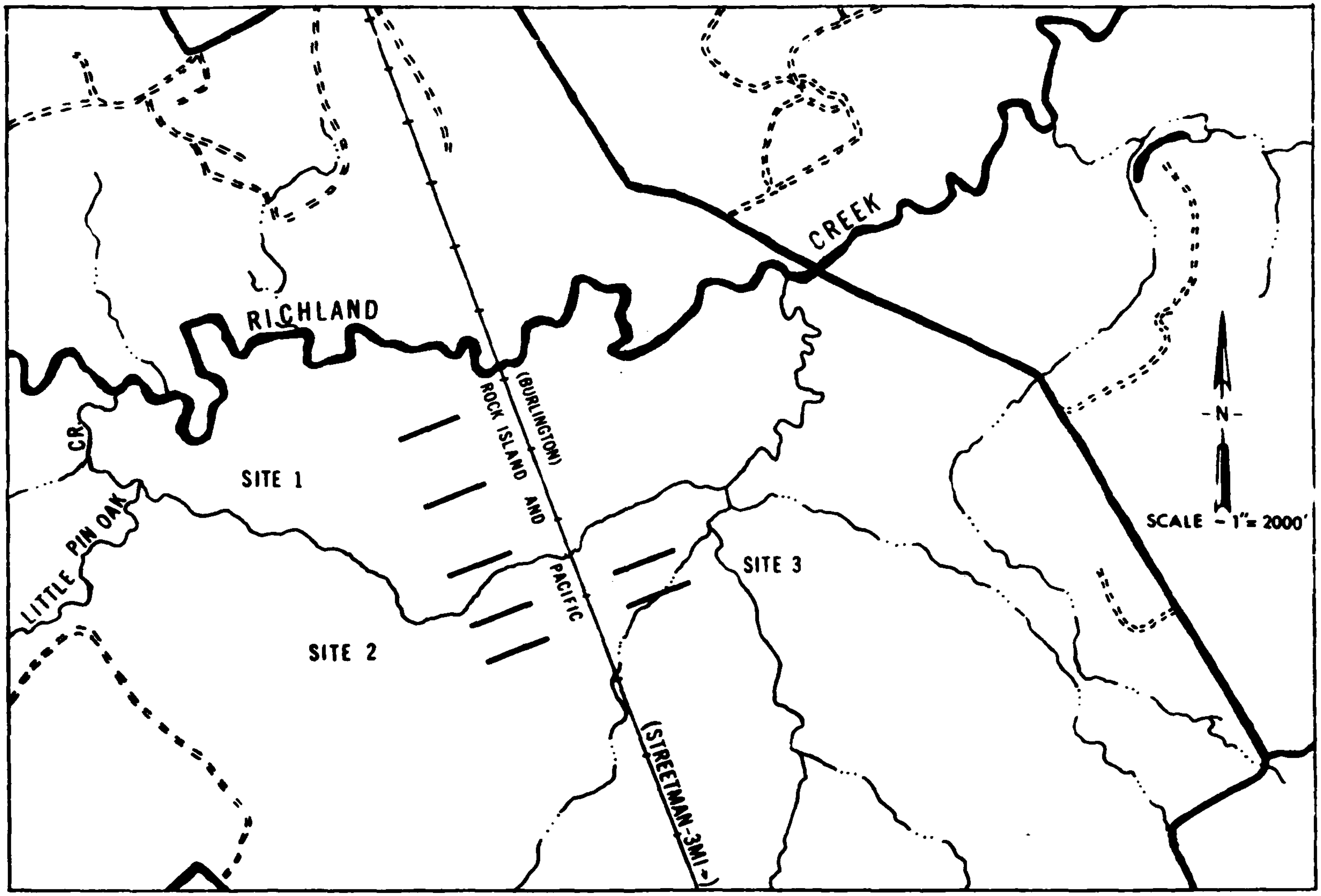


Figure II-03. Showing sites 1,2, and 3 and the position of transects within these sites.

Site 1 was located west of the railroad tracks and south of Richland Creek (Fig. II-03). Water stands in occasional depressions following flooding. Site 2 was characterized by the presence of a shallow swamp as well as somewhat better drained areas with an occasional wet depression. This site was located across a small creek south of Site 1 (Fig. II-03). Site 3 was east of the railroad tracks opposite Site 2 (Fig. II-03). It had water standing in depressions and was transected by an intermittant creek.

Results

Site 1

Only eleven woody plant species were recorded at Site 1. This forest contained a preponderance of Texas sugarberry (*Celtis laevigata*) associated with occasional trees of cedar elm (*Ulmus crassifolia*) (Table II-09). Green ash (*Fraxinus pensylvanica*) and swamp privet (*Forestiera acuminata*) were mostly confined to wet locations. Probably as a result of flooding and grazing, the forest showed comparatively little regeneration with most species having fewer trees in the 1-10 cm size class (Table II-10). Only occasional trees of cedar elm, green ash and bur oak had diameters at breast height greater than 40 cm. The shrub layer was generally lacking, allowing for a good growth of herbaceous plants. Ground cover was mostly wild rye (*Elymus* sp.) And wild onion (*Allium* sp.).

Site 2

At Site 2, Texas sugarberry was still by far the dominant species (Table II-11). Cedar elm was only occasionally observed. Green ash and swamp privet were common in the wetter areas. Only nine woody species were recorded at Site 2. Wild rye and wild onion were prevalent as a result of an open understory. The forest was composed mostly of medium-sized trees in the 11-20 and 21-30 cm size classes (Table II-12). Tree density was low as indicated by the presence of only 2.4 trees per plot.

Site 3

Site 3 was somewhat more open than Sites 1 and 2. Only 1.16 trees were recorded per plot (Table II-13). Twelve woody species were recorded in this study site. Texas sugarberry was the dominant species but less strongly so than in the other two sites. Cedar elm and green ash were relatively more abundant (Table II-13). Wild rye and wild onion comprised most of the ground cover. Most trees present were of medium size (Table II-14).

Table II-09. Frequency, density and dominance data for plant species located at Site 1.

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
<u>Celtis laevigata</u>	61.3	62.0	1.00	60.4	65.8	188.2
<u>Ulmus crassifolia</u>	11.7	11.8	0.13	7.8	20.2	39.8
<u>Forestiera acuminata</u>	4.3	4.4	0.24	14.5	1.1	20.0
<u>Fraxinus pensylvanica</u>	5.0	5.1	0.08	4.6	4.7	14.4
<u>Bumelia lanuginosa</u>	5.7	5.7	0.08	5.0	2.8	13.5
<u>Sapindus Saponaria</u>	3.3	3.4	0.04	2.6	1.3	7.3
<u>Crataegus</u> spp.	3.7	3.7	0.04	2.2	0.5	6.4
<u>Fraxinus americana</u>	2.3	2.4	0.02	1.4	1.8	5.6
<u>Quercus macrocarpa</u>	0.7	0.7	0.01	0.4	1.6	2.7
<u>Morus rubra</u>	0.7	0.7	0.01	0.4	0.1	1.2
<u>Gleditsia triacanthos</u>	0.3	0.3	**	0.2	***	0.5
Total	----	100.2	1.65	99.5	99.9	299.6

* Sum of relative frequency, relative density, and relative dominance.

** Value less than 0.01.

*** Value less than 0.1.

Table II-10. Size classes (dbh) of plant species located at Site 1.

Species	Size Classes (cm) 1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Celtis laevigata	24	154	107	17						
Ulmus crassifolia	2	4	12	16	5					
Forestiera acuminata	71	1								
Fraxinus pensylvanica	6	11	4	1	1					
Bumelia lanuginosa	12	7	6							
Sapindus Saponaria	4	7	2							
Crataegus spp.	6	5								
Fraxinus americana		3	3	1						
Quercus macrocarpa				1	1					
Morus rubra	1	1								
Gleditsia triacanthos	1									
Total	127	193	134	36	7					

Table II-11. Frequency, density and dominance data for plant species located at Site 2.

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Celtis laevigata	68.0	55.1	1.40	58.9	61.4	175.4
Fraxinus pensylvanica	24.5	19.8	0.44	18.4	21.4	59.6
Ulmus crassifolia	12.5	10.1	0.17	7.2	10.4	27.7
Forestiera acuminata	6.5	5.3	0.25	10.3	0.8	16.4
Bumelia lanuginosa	5.5	4.5	0.06	2.5	1.4	8.4
Quercus macrocarpa	2.5	2.0	0.03	1.1	3.6	6.7
Sapindus Saponaria	2.0	1.6	0.02	0.8	0.6	3.0
Crataegus spp.	1.5	1.2	0.02	0.6	0.4	2.2
Gleditsia triacanthos	0.5	0.4	0.01	0.2	**	0.6
Total	----	100.0	2.40	100.0	100.0	300.0

* Sum of relative frequency, relative density, and relative dominance.

** Value less than 0.1.

Table II-12. Size classes (dbh) of plant species located at Site 2.

Species	Size Classes (cm)									
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Celtis laevigata	24	160	81	14						
Fraxinus pensylvanica	34	19	21	11	2					
Ulmus crassifolia	6	12	10	6						
Forestiera acuminata	47	2								
Bumelia lanuginosa	4	7	1							
Quercus macrocarpa				5						
Sapindus Saponaria	1	2	1							
Crataegus spp.	1	2								
Gleditsia triacanthos	1									
Total	118	204	114	36	2					

Table II-13. Frequency, density and dominance data for plant species located at Site 3.

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Celtis laevigata	30.0	34.7	0.45	39.8	37.3	111.8
Ulmus crassifolia	20.0	23.1	0.23	19.0	29.7	72.7
Fraxinus pensylvanica	16.5	19.1	0.22	19.5	17.6	56.2
Bumelia lanuginosa	6.5	7.5	0.08	7.1	4.5	19.1
Quercus macrocarpa	2.0	2.3	0.02	1.8	7.7	11.8
Crataegus spp.	3.5	4.0	0.05	4.4	1.9	10.3
Gleditsia triacanthos	3.5	4.0	0.04	3.5	0.1	7.6
Morus rubra	1.5	1.7	0.02	1.3	0.8	3.8
Maclura pomifera	1.5	1.7	0.02	1.3	0.4	3.4
Sapindus Saponaria	0.5	0.6	0.01	0.4	**	1.0
Others***		1.2	0.02	0.8	**	2.0
Total	----	99.9	1.16	99.8	100.0	299.7

* Sum of relative frequency, relative density, and relative dominance.

** Value less than 0.1.

*** Other species present listed in order of decreasing importance values: Ilex decidua, Forestiera acuminata.

Table II-14. Size classes (dbh) of plant species located at Site 3.

Species	Size Classes (cm) 1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Celtis laevigata	5	48	27	10						
Ulmus crassifolia	2	15	12	13	3					
Fraxinus pensylvanica	2	21	20	1						
Bumelia lanuginosa	6	4	6							
Quercus macrocarpa		1		1		2				
Crataegus spp.	6	3	1							
Gleditsia triacanthos	8									
Morus rubra	1	1	1							
Maclura pomifera	1	2								
Sapindus Saponaria	1									
Others*	2									
Total	34	95	67	25	3	2				

* See Table II-13 for a list of other species present.

STUDY AREA 7

Introduction

Study Area 7 was located in southeastern Leon County just west and north of the junction of Lower Keechi Creek and the Trinity River (Fig. II-04). Study sites were situated within the floodplain of the Trinity River, on the adjacent slope to upland, and on the more level upland. Collection of data was accomplished during the spring of 1973.

Topographically, the study sites varied from nearly flat, poorly drained floodplain to the more elevated slope and ridge areas. Geologically, the area is composed of Alluvium deposits of Recent origin within the Quaternary Period. Included perhaps are some Deweyville deposits as well as a few small inliers of Tertiary formations. Fluviatile terrace deposits of Pleistocene origin within the Quaternary Period were also present.

In the vicinity of the junction of Lower Keechi Creek and the Trinity River, the major soil types are the Tuscumbia, Travis and Bienville loamy fine sand. Probably the most extensive soil is the Tuscumbia, which is similar to Kaufman Clay. This soil occupies nearly level, slightly concave bottomland flood plains. This somewhat slowly drained soil is poorly suited for dwellings, sewage systems, local roads, most recreational uses, and cropland. It is well suited for woodland and wetland wildlife and for pond reservoir areas and is fairly well suited for grassland and woodland (U.S. Department of Agriculture, unpublished data).

The Travis soil occupies the slope area between the low, poorly drained Tuscumbia soil adjoining the creek and the more elevated and level Bienville loamy fine sand soil. The degree of slope (5-12%) hinders the utility of this soil for some uses.

The Bienville loamy fine sand soil occupies the most elevated portions of the study area, occurring on the broad, nearly level to gently sloping crests west of Lower Keechi Creek. This soil is somewhat excessively drained as a result of a low moisture holding capacity and is seasonally droughty during the summer and fall months. It is well suited for dwellings, septic tank filter beds, local roads and streets, and light industry. It has fair suitability for camp and picnic areas, playgrounds, most

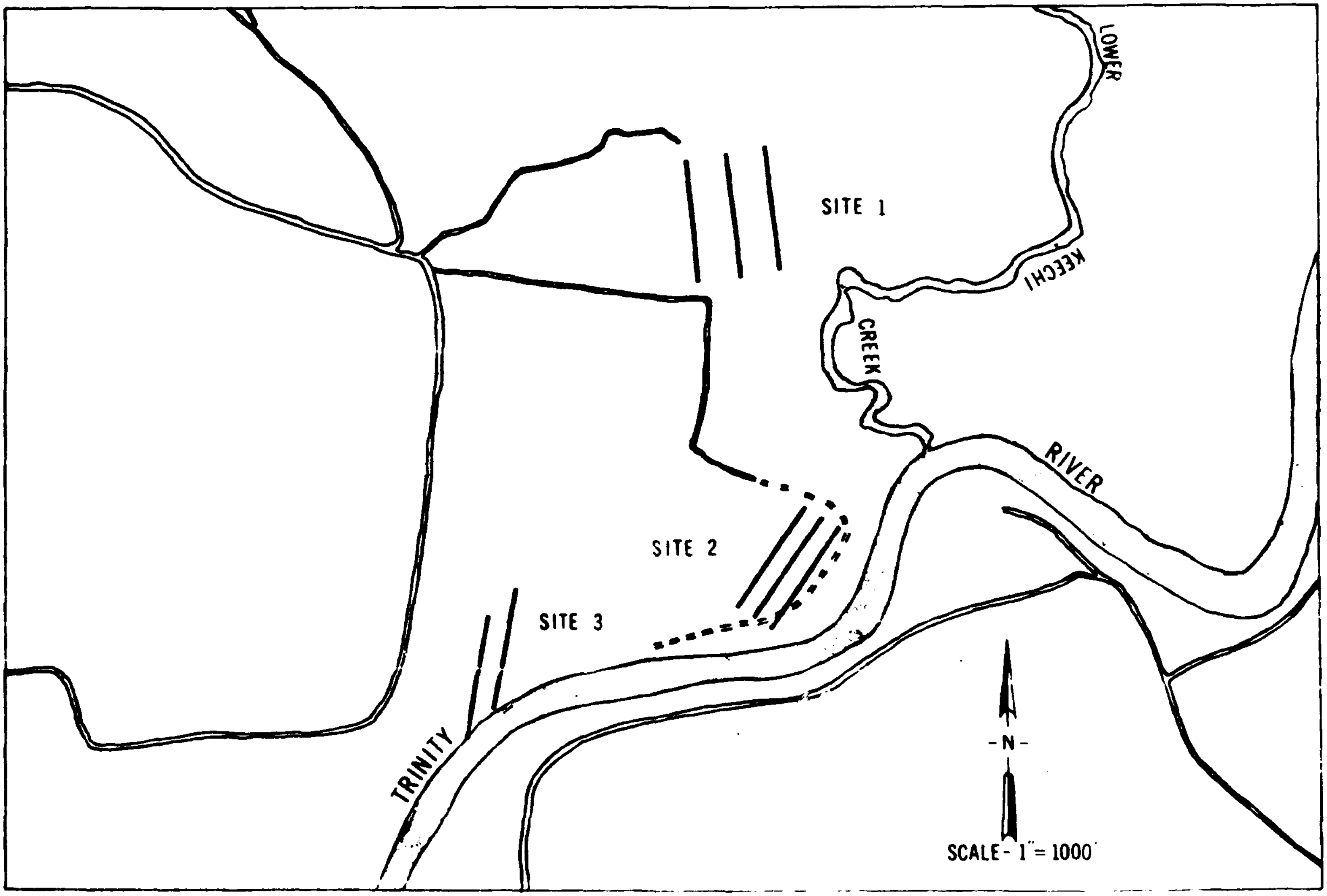


Figure II-04. Showing sites 1,2, and 3 and the position of transects within these sites.

wildlife and woodland. Although the Bienville loamy fine sand soil was classified as poorly suited for cropland and grassland, some parts have been cleared for pasture in the vicinity of the study area.

The three study sites were forested, but some nearby land has been cleared for pasture. Grazing by cattle of the entire area was evident.

Land Use

The number of inhabitants of sparsely populated Leon County dropped from 9,951 in 1960 to 8,738 in 1970 (*Texas Almanac*, 1971). Buffalo, the largest town in the county, had a population of 1,242 in 1970 while Centerville, the county seat, had 831. Less than 3400 people lived in towns in 1970 in Leon County. The economy is based on agriculture. Of the $16,724,000 total income, $10,000,000 was farm income, while minerals, chiefly oil and gas, contributed $4,645,000. Eighty percent of the agricultural income is derived from livestock. Cotton, grain, melons and peas are the main crops.

Of the more than 693,000 acres of land in Leon County, less than 12,000 acres were classified as non-commercial in 1970 (Table II-15) (Leon County Conservation Needs Committee, 1970). Between 1958 and 1967, non-commercial area increased from 9,865 acres to 11,556. Most of the increase was in the urban and built-up category, representing fringe growth of the small towns and an influx of people , mainly from Houston, into recreation areas.

Of the county's total area, over 48% was in pasture and range in 1970. Between 1958 and 1967, pastureland acreage increased from 99,177 acres to 320,100 acres while range jumped from 4,115 to 17,075 acres. Most of the gain was at the expense of cropland, which fell from 150,593 to 61,292 acres, and of forest, which dropped from 434,363 acres in 1958 to 292,800 acres in 1967. The classification "other land" dropped almost 50%, from 5,208 acres to 2,189 acres. With the county's loss of population and the trend away from intensive row cropping and toward cattle raising, the number of farmsteads has apparently declined.

Leon County can be expected to see future development of certain areas for outdoor recreation. An appraisal of potential for outdoor recreational development in Leon County (Anonymous, 1967b) predicts a high potential for picnicking and field sports, transient camping, fishing,

Table II-15. Leon County land area (in acres).
(from Leon County Conservation Needs Committee, 1970.)

Land Use	1958	1967
Total land area	703,320	705,012
Less: Federal non-cropland	0	0
Less: Urban and built-up	8,824	10,156
Less: Small water areas	1,040	1,400
Total non-commercial area	9,864	11,556
Total commercial farm and forest area	693,456	693,456
Cropland	150,593	61,292
Pasture	99,177	320,100
Range	4,115	17,075
Forest	434,363	292,800
Other land	5,208	2,189

deer hunting, riding stables, and shooting preserves. Vacation cabins and homesites, as well as water sports areas, received a high medium rating. Perhaps due to the lack of proximity to large reservoirs for fishing and boating, weekend home building has not yet experienced the boom as witnessed in Polk, San Jacinto and Liberty counties along the lower Trinity River.

Methods and Procedures

Study Area 7 was comprised of three study sites (Fig. II-04). The more undisturbed plant communities were selected to represent the woody vegetation of the area. Transects were positioned as shown in Figure II-04. A total of 800 plots ($5m^2$) were analyzed, 300 each at Sites 1 and 2 and 200 at Site 3.

Description of Study Sites

Site 1 was located on a slope and level ridge west of Lower Keechi Creek and north of its junction with the Trinity River (Fig. II-04). Transects were located along contours on the ridge and one-third and two-thirds of the way down the slope. The area was well drained and supported a greater habitat diversity than the other two study sites. Site 2 was in a cedar elm flat west of Lower Keechi Creek and north of the Trinity River (Fig. II-04). The site was poorly drained and showed evidence of flooding. Several permanently ponded or excessively moist areas were present. Site 3 was composed of a more rolling topography traversed by several drainages and an intermittant creek. It was located adjacent to the river west of Lower Keechi Creek (Fig. II-04).

Results

Site 1

The forest at Site 1 had a more varied habitat than the other two sites at Study Area 7 and, with 34 woody species recorded, the greatest diversity of species. American beautyberry (*Callicarpa americana*) dominated the understory shrubs on both slope and ridge areas. Along the ridge, post oak (*Quercus stellata*) and black hickory (*Carya texana*) were dominant tree species while farkleberry (*Vaccinium arboreum*), Indian cherry (*Rhamnus caroliniana*), sweetgum (*Liquidambar Styraciflua*) and flowering dogwood (*Cornus florida*) were less abundant woody species. Post oak was still dominant on the upper portion of the slope.

Abundant associated species were black walnut (*Juglans nigra*) and sweetgum. Black hickory was less frequent. Two-thirds of the way down the slope, eastern redbud (*Cercis canadensis*), winged elm (*Ulmus alata*), black walnut, sweetgum and red oak (*Quercus falcata*) occurred with nearly equal abundance.

Table II-16 is a summary of the woody vegetational data gathered at Site 1. Overall, American beautyberry was the dominant understory species and post oak the dominant overstory species (Table II-16). Black hickory, sweetgum and black walnut were also prevalent. Most individuals were less than 40 cm in diameter at breast height (Table II-17). Only two recorded trees of post oak and one of sweetgum exceeded 50 cm in diameter.

Site 2

Site 2 was strongly dominated by cedar elm (*Ulmus crassifolia*) in the overstory and by deciduous holly (*Ilex decidua*) in the understory (Table II-18). Much less abundant were willow oak (*Quercus Phellos*), honey locust (*Gleditsia triacanthos*), hawthorn (*Crataegus* spp.) and Texas sugarberry (*Celtis laevigata*). Permanently ponded or excessively wet areas were dominated by swamp privet (*Forestiera acuminata*), overcup oak (*Quercus lyrata*), green ash (*Fraxinus pensylvanica*) and water locust (*Gleditsia aquatica*). Except for thickets of swamp privet in portions of the wet areas, the forest was open. Sedges (*Carex* spp) comprised much of the herbaceous layer. Most trees at Site 2 were less than 40 cm in dbh (Table II-19). There were, however, a few widely scattered individuals of cedar elm, willow oak and overcup oak with larger diameters. Seventeen woody species were recorded at Site 2.

Site 3

Fourteen woody species were recorded at Site 3, with Texas sugarberry, cedar elm and pecan (*Carya illinoinensis*) being the principal species (Table II-20). Deciduous holly and swamp privet were the dominant understory species. Swamp privet, green ash and waterlocust dominated the occasional wet areas. The forest was generally open except along the river where greenbriar (*Smilax* spp) and blackberry (*Rubus* spp) formed dense clumps. Most trees had dbh less than 50 cm (Table II-21). Only 1.87 trees per plot were recorded.

Table II-16. Frequency, density and dominance data for plant species located in Site 1.

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Callicarpa americana	84.0	31.4	2.41	48.2	1.9	81.5
Quercus stellata	14.7	5.5	0.18	3.5	29.4	38.4
Carya texana	13.7	5.1	0.15	3.0	12.7	20.8
Liquidambar Styraciflua	9.3	3.5	0.12	2.5	12.5	18.5
Juglans nigra	15.0	5.6	0.17	3.4	6.9	15.9
Vaccinium arboreum	15.7	5.9	0.29	5.9	1.2	13.0
Cercis canadensis	14.0	5.2	0.24	4.9	1.5	11.6
Forestiera ligustrina	17.3	6.5	0.22	4.5	0.6	11.6
Ulmus alata	10.7	4.0	0.20	3.9	2.0	9.9
Quercus falcata	7.0	2.6	0.11	2.2	4.6	9.4
Others**		24.5	0.90	18.1	26.8	69.4
Total	----	99.8	4.99	100.1	100.1	300.0

* Sum of relative frequency, relative density, and relative dominance.

** Other species present listed in order of decreasing importance values: Cornus florida, Ulmus crassifolia, Fraxinus americana, Rhamnus caroliniana, Quercus marilandica, Sassafras albidum, Celtis laevigata, Ulmus spp. (includes U. americana and U. rubra), Bumelia lanuginosa, Tilia americana (includes T. caroliniana and T. floridana), Carya cordiformis, Ilex decidua, Nyssa sylvatica, Fraxinus pensylvanica, Ilex vomitoria, Morus rubra, Quercus nigra, Platanus occidentalis, Myrica cerifera, Crataegus spathulata, Crataegus spp., Zanthoxylum Clava-herculis, Crataegus Marshallii, Diospyros virginiana.

Table II-17. Size classes (dbh) of plant species located at Site 1.

Species	Size Classes (cm)									
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Callicarpa americana	722									
Quercus stellata	10	13	8	19	1	2				
Carya texana	16	9	16	4						
Liquidambar Styraciflua	21	4	5	5	1	1				
Juglans nigra	36	9	4	2						
Vaccinium arboreum	87		1							
Cercis canadensis	69	4								
Forestiera ligustrina	65	2								
Ulmus alata	54	4	1							
Quercus falcata	27	2	1	1	2					
Others*	198	50	14	8	1					
Total	1305	97	50	39	5	3				

* See Table II-16 for a list of other species present.

Table II-18. Frequency, density and dominance data for plant species located in Site 2.

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Ulmus crassifolia	23.0	29.2	0.30	22.1	60.5	111.8
Ilex decidua	21.3	27.1	0.50	37.0	3.2	67.3
Quercus Phellos	2.3	3.0	0.02	1.7	13.3	18.0
Gleditsia triacanthos	5.7	7.2	0.10	7.6	2.3	17.1
Crataegus spp.	7.3	9.3	0.08	6.1	1.5	16.9
Forestiera acuminata	2.3	3.0	0.18	13.0	0.8	16.8
Quercus lyrata	2.7	3.4	0.03	2.0	6.0	11.4
Fraxinus pensylvanica	3.0	3.8	0.03	2.5	4.1	10.4
Celtis laevigata	2.3	3.0	0.02	1.7	3.1	7.8
Gleditsia aquatica	2.3	3.0	0.02	1.7	2.5	7.2
Others**		7.9	0.07	4.6	2.7	15.2
Total	----	99.9	1.35	100.0	100.0	299.9

* Sum of relative frequency, relative density, and relative dominance.

** Other species present listed in order of decreasing importance values: *Bumelia lanuginosa*, *Diospyros virginiana*, *Carya illinoinensis*, *Sophora affinis*, *Planera aquatica*, *Crataegus spathulata*. *Sabal minor*, not included in column totals, had a density of 0.01 individuals per plot.

Table II-19. Size classes (dbh) of plant species located at Site 2.

Species	Size Classes (cm)									
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Ulmus crassifolia	11	10	37	29	3					
Ilex decidua	151									
Quercus Phellos		1	1	1	1	2	1			
Gleditsia triacanthos	26	5								
Crataegus spp.	20	5								
Forestiera acuminata	53									
Quercus lyrata	3		1	3	1					
Fraxinus pensylvanica	[illegible]	2	1	2						
Celtis laevigata	4		1	2						
Gleditsia aquatica	2	2	2	1						
Others*	16	1	1	1						
Total	291	26	44	39	5	2	1			

* See Table II-18 for a list of other species present.

Table II-20. Frequency, density and dominance data for plant species located at Site 3.

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Celtis laevigata	30.5	31.0	0.61	33.3	17.7	82.0
Ulmus crassifolia	18.5	18.8	0.29	15.8	33.2	67.8
Carya illinoinensis	5.5	5.6	0.07	3.8	25.3	34.7
Forestiera acuminata	7.5	7.6	0.39	21.3	3.1	32.0
Ilex decidua	15.5	15.7	0.23	12.3	2.1	30.1
Fraxinus pensylvanica	4.0	4.1	0.04	2.2	11.0	17.3
Gleditsia aquatica	7.0	7.1	0.08	4.1	3.5	14.7
Crataegus spp.	4.0	4.1	0.05	2.5	0.6	7.2
Gleditsia triacanthos	2.5	2.5	0.04	1.9	0.6	5.0
Bumelia lanuginosa	1.0	1.0	0.02	1.1	2.3	4.4
Others**		2.5	0.05	1.7	0.6	4.8
Total	----	100.0	1.87	100.0	100.0	300.0

* Sum of relative frequency, relative density, and relative dominance.

** Other species present listed in order of decreasing importance values: *Ulmus* spp. (includes *U. americana* and *U. rubra*), *Sophora affinis*, *Acer negundo*, *Vaccinium arboreum*.

Table II-21. Size classes (dbh) of plant species located at Site 3.

Species	Size Classes (cm)									
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Celtis laevigata	97	17	3	4						
Ulmus crassifolia	26	8	9	13	2					
Carya illinoinensis	7	3		1			1		2	
Forestiera acuminata	74	4								
Ilex decidua	45									
Fraxinus pensylvanica	2	1	1	1	2	1				
Gleditsia aquatica	5	2								
Crataegus spp.	8	1								
Gleditsia triacanthos	5	2								
Bumelia lanuginosa	3				1					
Others*	8	2	4							
Total	280	40	17	19	6	1	1		2	

* See Table II-20 for a list of other species present.

STUDY AREA 8

Introduction

The objective of this phase of the study was to analyze the woody vegetation of two swamps and associated terrestrial forests located in the vicinity of the Trinity River. Field work was accomplished during the fall of 1972. The study area was situated within San Jacinto County in southeast Texas. More specifically, it is located in the extreme eastern part of San Jacinto County between Shepherd, Texas and the Trinity River (Fig. II-05).

The topography of the area is flat to very gently rolling and occasionally characterized by the presence of depressions, sloughs and creeks. Geologically the area is composed of Alluvium deposits of Recent origin within the Quaternary Period. There are many small inliers of Tertiary formations and along minor streams outcroppings of Deweyville and Pleistocene formations occur. The Deweyville Formation lies along the western edge of the study area. There are three soils present, the Tuckerman loam, Bernaldo fine sandy loam, and the Kaufman clay (U.S. Department of Agriculture, unpublished data). The Tuckerman soils occupy nearly level concave areas and are generally poorly drained and ponded. They are poorly suited for dwellings, general recreation use, cropland or grassland but are suited for pond reservoir areas and woodland and wetland wildlife. The Bernaldo fine sandy loam soils occupy well-drained, slightly sloping sites generally adjacent to Tuckerman soils in our study area. They are suited for dwellings, woodland, grassland, cropland and wildlife. The Kaufman clay soils occupy the somewhat poorly drained bottomland floodplain areas. They are slightly better drained than the Tuckerman soils but are suited primarily for pond reservoir areas and woodland and wetland wildlife. They have some potential for grassland.

The vegetation of the study area was mostly woodland occupying both aquatic and terrestrial sites. Cleared sites within the study area were generally associated with roads and pipelines but more upland surrounding areas contain larger acreages of pasture and cropland. Grazing by cattle was evident and it appeared that all of the study area had been logged. Some swamp areas have not been logged since the early 1920's but other areas have been selectively logged within recent years.

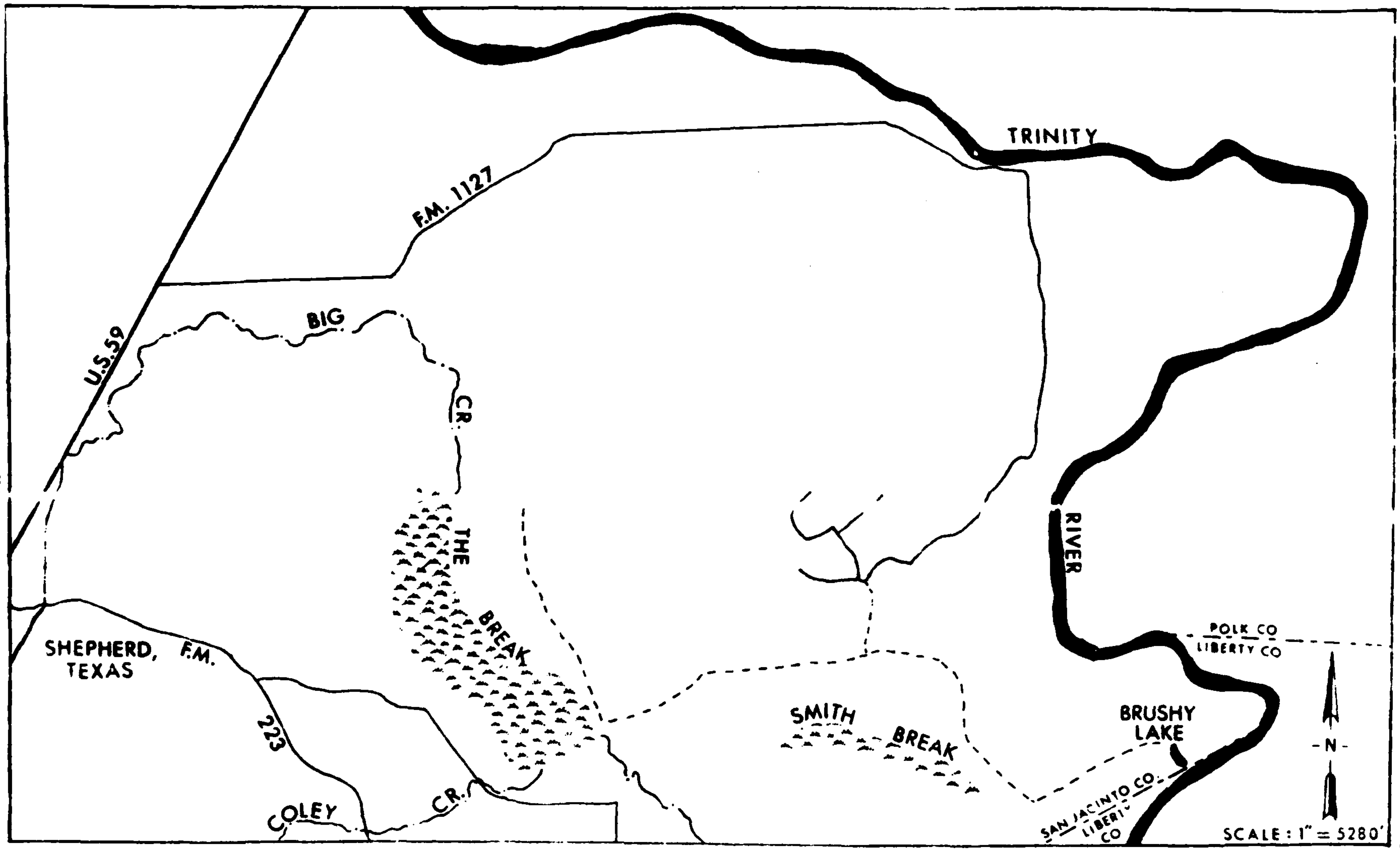


Figure II-05. Showing the study area in relation to the Trinity River.

Land Use

San Jacinto County is mainly a rural area, with less than 1900 people living in the two largest towns in the county. Most of the land is forested (Table II-22). Out of 399,360 acres, some 258,100 acres were in commercial forest in 1967, with an additional 58,59. acres of National Forest within the county. Between 1958 and 1967, cropland acreage declined by over 75%, while forest area declined about 10%. Pastureland acreage increased six times over, however, from 10,625 acres to 67,117 acres (Conservation Needs Committee, 1967).

Within easy driving distance of Houston and the coastal population concentrations, bordering Lake Livingston, and containing part of Sam Houston National Forest, San Jacinto County can expect to be increasingly affected by demands for outdoor recreation. An appraisal of potential for outdoor recreational developments in San Jacinto County (Miller, et al., 1967) indicated that water sports and fishing, vacation cabins, cottages and homesites, small and big game hunting, and campgrounds for transient camping and vacation sites have especially high potential for development.

The area of land used for pasture will probably slowly increase at the expense of cropland and forest. The major change will probably be in land developed for weekend and retirement homes. Polk and Liberty counties are already experiencing such a boom.

Within the study area, only the Bernaldo fine sandy loam soil, making up about a fourth of the total area, favors diversion of the land from forest to grassland, cropland, or housing developments. It is probably inevitable that suitable land of this type near the river will eventually be developed for weekend and retirement homes as has already been done in Polk County on the opposite bank. Large scale development might include almost all of this well-drained soil. The Kaufman clay and Tuckerman loam soils, however, do not lend themselves to uses more intense than timber, grazing, and wildlife. The current practice of grazing cattle beneath the forest during drier periods will likely remain the chief use of most of the area in the near future.

Table II-22. San Jacinto County land area (in acres).
(from Conservation Needs Committee, 1967.)

Land Use	1958	1967
Total land area	396,160	399,360
Less: Federal non-cropland (Sam Houston National Forest)	58,592	58,592
Less: Urban and built-up	3,284	3,390
Less: Small water areas	1,200	1,380
Total non-commercial area	63,076	63,362
Total commercial farm and forest area	333,084	335,998
Cropland	36,281	8,853
Pasture	10,625	67,117
Forest	284,463	258,100
Other land	1,715	1,928

Methods and Procedures

Six study sites composed the study area (Figs. II-06 and II-07). The more unique and undisturbed plant communities were selected for analysis. Transects were positioned within each study site as indicated in Figures II-06 and II-07. Plots in swamp areas were established with the use of twine strands transecting the swamp and marked at five meter intervals. A total of 2070 plots ($5m^2$) were analyzed. Three hundred plots were analyzed in each study site with the exception of Site 1 (550 plots) and Site 2 (320 plots).

Description of Study Sites

Sites 1 and 2 included two swamp areas referred to locally as The Break and Smith Break respectively. Water prevails year-round in these swamps and they are located on Tuckerman loam soils. Water depth was generally less than four feet. Sites 3, 4, 5, and 6 were more terrestrial although portions of these sites may be temporarily inundated. Sites 3 and 4 were located east of The Break, Site 5 was situated north of Smith Break and Site 6 was established west of Brushy Lake near the Trinity River (Figs. II-06 and II-07) . Site 3 was located on Kaufman clay and Bernaldo fine sandy loam soils. Site 4 probably transected all three soil types mentioned. Site 5 was situated on Kaufman clay soils and Site 6 on Tuckerman soils.

Results

Site 1 (The Break)

The Break is a swamp maintained by two creeks flowing incessently through its length. Big Creek, entering from the north, and Coley Creek, entering from the southwest, unite within The Break (Fig. II-06). Based on importance value, tupelo (*Nyssa aquatica*) was the overwhelmingly dominant tree species in the swamp (Table II-23). Bald cypress (*Taxodium distichum*) was somewhat prevalent. Both of these species showed good size-class distribution (Table II-24). Subdominants in The Break were Carolina ash (*Fraxinus caroliniana*) and red maple (*Acer rubrum*). Sweet-spire (*Itea virginica*) was the most abundant shrub. These latter three species contained representatives mostly in the size-class 1-10 cm (Table II-24).

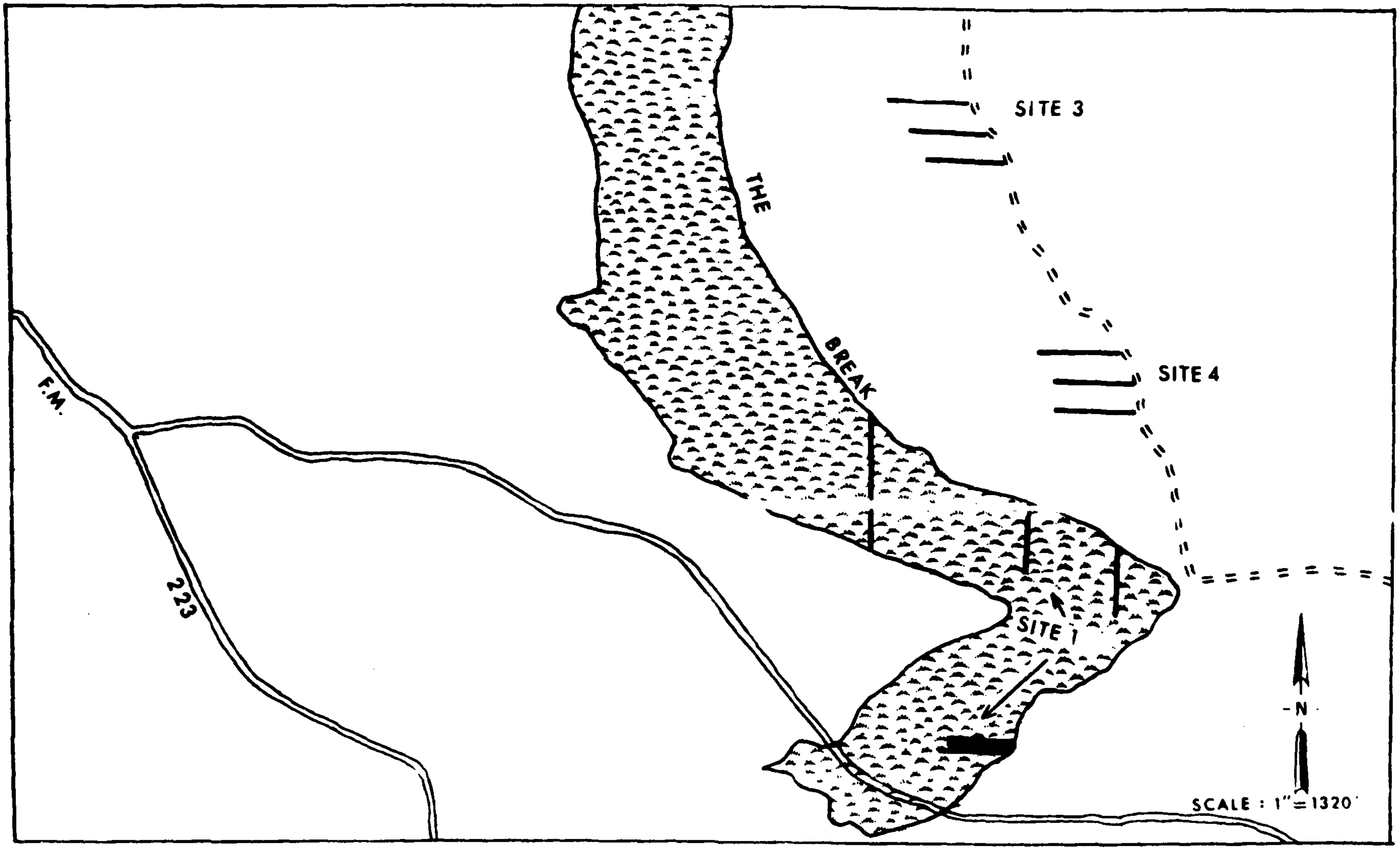


Figure II-06. Showing sites 1,3, and 4 and the position of transects within these sites.

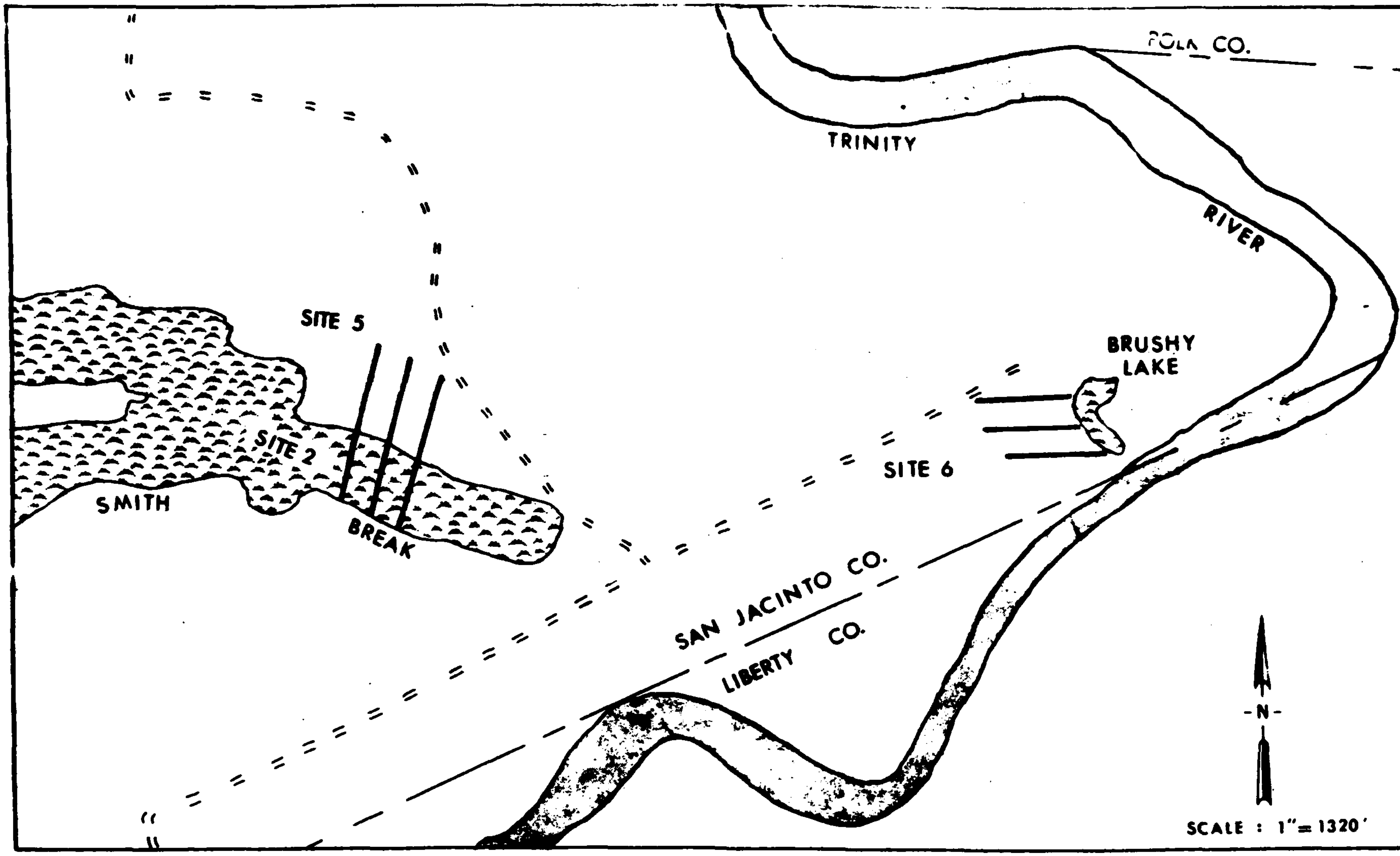


Figure II-07. Showing sites 2,5, and 6 and the position of transects within these sites.

Table II-23. Frequency, density and dominance data for plant species located in Site 1 (The Break).

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Nyssa aquatica	81.3	36.7	2.43	49.6	72.6	158.9
Taxodium distichum	34.9	15.8	0.51	10.3	24.0	50.1
Fraxinus caroliniana	31.3	14.1	0.53	10.8	0.6	25.5
Itea virginica	24.2	10.9	0.61	12.3	0.1	23.3
Acer rubrum	15.1	6.8	0.38	7.7	0.9	15.4
Planera aquatica	10.0	4.5	0.13	2.6	0.2	7.3
Liquidambar Styraciflua	3.5	1.6	0.04	0.9	1.1	3.6
Fraxinus pensylvanica	4.2	1.9	0.07	1.4	0.2	3.5
Carya aquatica	2.9	1.3	0.06	1.2	0.1	2.6
Quercus lyrata	3.6	1.6	0.04	0.8	0.2	2.6
Others**		4.9	0.17	2.0	0.1	7.0
Total	----	100.1	4.97	99.6	100.1	299.8

* Sum of relative frequency, relative density, and relative dominance.

** Other species present listed in order of decreasing importance values: *Ulmus* spp. (Includes *U. americana* and *U. rubra*), *Styrax americana*, *Cephalanthus occidentalis*, *Celtis laevigata*, *Quercus Phellos*, *Cornus racemosa*, *Diospyros virginiana*, *Quercus falcata*, *Callicarpa americana*, *Carpinus caroliniana*, *Gleditsia aquatica*, *Ilex decidua*, *Ilex opaca*, *Ilex vomitoria*, *Quercus nigra*, *Quercus Shumardii*, *Ulmus crassifolia*. *Sabal minor*, not included in column totals, had a density of 0.07 individuals per plot.

Table II-24. Size classes (dbh) of plant species located at Site 1 (The Break).

Species	Size Classes (cm)									
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Nyssa aquatica	679	318	122	74	54	34	19	14	6	19
Taxodium distichum	83	63	41	28	24	16	12	9	1	1
Fraxinus caroliniana	283	7								
Itea virginica	333									
Acer rubrum	188	12	6	2						
Planera aquatica	66	2	1							
Liquidambar Styraciflua	12	2	4	2	2	2				
Fraxinus pensylvanica	33	5		1						
Carya aquatica	31	1								
Quercus lyrata	18	2		1						
Others*	61	3								
Total	1787	415	174	109	80	52	31	23	7	20

* See Table II-23 for a list of other species present.

Site 2 (Smith Break)

The water in Smith Break (Fig II-07) was more stagnant than that in The Break. Smith Break was not transected by a creek but instead appeared to be spring fed with drainage into Big Creek. A drainage ditch has also been excavated from the east end of Smith Break to the Trinity River. Dominant woody species in Smith Break were tupelo and bald cypress (Table II-25). Each of these species showed good size class distribution (Table II-26). Subdominants in this site were water elm (Planera aquatica) and common buttonbush (Cephalanthus occidentalis).

Both Smith Break and The Break were dominated by tupelo and bald cypress but subdominant species varied in the two sites (Tables II-23 and II-25). In the areas studied, The Break had a greater species diversity as indicated by the larger number of species recorded (27 species as compared to 10 in Smith Break). The Break, in addition, averaged 4.97 plants per plot whereas Smith Break averaged 1.53.

Site 3 (Palmetto area near The Break)

A forested area east of The Break with a rather uniform population of palmetto was analyzed (Fig. II-06). The palmettos had a frequency of 81.7% and a density of 4.76 plants per plot. This species, as a result, dominated the shrub layer of vegetation in this community. Dominant upper-layer species were water oak (Quercus nigra), sweetgum and southern red oak (Table II-27). These species were generally represented in the higher size classes (Table II-28). Texas sugarberry and pecan (Carya illinoinensis) were also prevalent. Mid-layer subdominants included deciduous holly (Ilex decidua) and snowdrop-tree (Halesia diptera). Thirty-eight woody species were recorded in plots in this area. It should be noted that a honey locust tree measuring 78 inches in circumference and 88 feet in height and having a crown spread of 57 feet is a possible state champion. Its index is 180 as compared to the present state champion's index of 147-1/2.

Site 4 (Wooded area near The Break)

Site 4 was a fairly open wooded area dominated by hawthorn (Crataegus spp.) and cedar elm (Fig. II-06) (Table II-29). Cedar elm trees were less than 40 cm in dbh and hawthorn trees were, with two exceptions, entirely within the 1-10 cm size class (Table II-30). Willow oak, Texas sugarberry, black oak (Quercus velutina) and overcup oak

Table II-25. Frequency, density and dominance data for plant species located in Site 2 (Smith Break).

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Nyssa aquatica	20.3	19.4	0.32	21.0	70.9	111.3
Taxodium distichum	25.3	24.2	0.32	20.6	26.7	71.5
Planera aquatica	25.9	24.8	0.38	24.9	1.3	51.0
Cephalanthus occidentalis	16.9	16.1	0.28	18.6	0.3	35.0
Fraxinus pensylvanica	5.0	4.8	0.06	3.9	0.2	8.9
Sesbania Drummondii	4.7	4.5	0.07	4.3	**	8.8
Forestiera acuminata	3.8	3.6	0.07	4.3	0.3	8.2
Gleditsia aquatica	2.2	2.1	0.03	2.0	0.2	4.3
Quercus lyrata	0.3	0.3	***	0.2	**	0.5
Quercus Phellos	0.3	0.3	***	0.2	**	0.5
Total	-	100.1	1.53	100.0	99.9	300.0

* Sum of relative frequency, relative density, and relative dominance.

** Value less than 0.1.

*** Value less than 0.01.

Table II-26. Size classes (dbh) of plant species located in Site 2 (Smith Break).

Species	Size Classes (cm)									
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Nyssa aquatica	6	10	9	11	10	10	17	9	5	16
Taxodium distichum	8	14	27	18	12	11	6	3		2
Planera aquatica	108	13	1							
Cephalanthus occidentalis	91									
Fraxinus pensylvanica	13	6								
Sesbania Drummondii	21									
Forestiera acuminata	21									
Gleditsia aquatica	8		2							
Quercus lyrata	1									
Quercus Phellos	1									
Total	278	43	39	29	22	21	23	12	5	18

Table II-27. Frequency, density and dominance data for plant species located in a palmetto area about one-half mile east of The Break (Site 3).

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Quercus nigra	12.0	6.1	0.13	5.3	21.6	33.0
Liquidambar Styraciflua	13.3	6.8	0.18	7.2	16.4	30.4
Quercus falcata	11.3	5.8	0.17	5.5	11.3	22.6
Ilex decidua	17.3	8.8	0.22	8.9	1.0	18.7
Celtis laevigata	9.7	4.9	0.17	5.5	7.9	18.3
Carya illinoinensis	13.7	7.0	0.15	6.1	4.7	17.8
Halesia diptera	14.3	7.3	0.20	8.0	0.6	15.9
Gleditsia triacanthos	12.7	6.5	0.15	6.0	2.9	15.4
Ulmus alata	11.7	5.9	0.15	6.1	2.7	14.7
Ulmus spp.**	7.0	3.6	0.07	3.0	7.4	14.0
Others***		37.3	0.87	38.3	23.7	99.5
Total	----	100.2	2.46	99.9	100.2	300.3

* Sum of relative frequency, relative density, and relative dominance.

** Includes *U. americana* and *U. rubra.*

*** Other species present listed in decreasing order of importance values: *Quercus Prinus*, *Callicarpa americana*, *Quercus velutina*, *Ilex vomitoria*, *Carpinus caroliniana*, *Ilex opaca*, *Viburnum dentatum*, *Fraxinus pensylvanica*, *Sambucus canadensis*, *Diospyros virginiana*, *Crataegus spp.*, *Cornus racemosa*, *Morus rubra*, *Nyssa sylvatica*, *Acer rubrum*, *Crataegus spathulata*, *Crataegus Marshallii*, *Cercis canadensis*, *Halesia carolina*, *Carya cordiformis*, *Aralia spinosa*, *Bumelia lanuginosa*, *Fraxinus americana*, *Prunus mexicana*, *Quercus lyrata*, *Quercus Shumardii*, *Ulmus crassifolia*, *Zanthoxylum Clava-Herculis*. *Sabal minor*, not included in column totals, had a density of 4.76 individuals per plot and a frequency of 81.7%.

Table II-28. Size classes (dbh) of plant species located in Site 3 (palmetto area) about one-half mile east of Site 1 (The Break).

Species	Size Classes (cm)									
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Quercus nigra	21	6	2	3	2	1	1	1	2	
Liquidambar Styraciflua	21	12	11	5	1	2	1			
Quercus falcata	22	11	3	2			3			
Ilex decidua	66									
Celtis laevigata	25	6	3	6		1				
Carya illinoinensis	24	13	7	1						
Halesia diptera	58	1								
Gleditsia triacanthos	35	5	2	2						
Ulmus alata	31	12	2							
Ulmus spp.*	13		2	5	2					
Others**	235	26	14	4	2	1		1	1	
Total	551	92	46	28	7	5	5	2	3	

* Includes *U. americana* and *U. rubra.*

** See Table II-27 for a list of other species present.

Table II-29. Frequency, density and dominance data for plant species located east of the southern end of The Break (Site 4).

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Crataegus spp.	51.7	21.8	1.22	30.5	2.7	55.0
Ulmus crassifolia	32.0	13.5	0.42	10.4	27.3	51.2
Ilex decidua	33.3	14.0	0.60	15.1	1.3	30.4
Gleditsia triacanthos	29.3	12.4	0.52	13.1	4.3	29.8
Quercus Phellos	8.0	3.4	0.10	2.5	18.8	24.7
Celtis laevigata	11.7	4.9	0.13	3.3	12.8	21.0
Diospyros virginiana	20.7	8.7	0.39	9.8	1.0	19.5
Quercus velutina	4.0	1.7	0.04	1.1	12.0	14.8
Quercus lyrata	3.7	1.5	0.04	0.9	9.8	12.2
Others**		18.0	0.54	13.3	9.8	41.1
Total	----	99.9	4.00	100.0	99.8	299.7

* Sum of relative frequency, relative density, and relative dominance.

** Other species present listed in order of decreasing importance values: Carya aquatica, Ilex vomitoria, Ulmus spp. (includes U. americana and U. rubra), Morus rubra, Crataegus spathulata, Quercus nigra, Liquidambar Styraciflua, Halesia diptera, Carya illinoinensis, Crataegus Marshallii, Acer rubrum, Bumelia lanuginosa, Carpinus caroliniana, Sapindus Saponaria, Citrus trifoliata, Taxodium distichum, Pinus taeda, Quercus falcata. Sabal minor, not included in column totals, had a density of 1.74 individuals per plot.

Table II-30. Size classes (dbh) of plant species located east of the southern end of The Break (Site 4).

Species	Size Classes (cm)									
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Crataegus spp.	364	2								
Ulmus crassifolia	44	40	25	16						
Ilex decidua	161									
Gleditsia triacanthos	141	13	2	1						
Quercus Phellos	20		1		2	4	2	1		
Celtis laevigata	16		18	4	2					
Diospyros virginiana	117	1								
Quercus velutina	6	1			2	3	1			
Fraxinus pensylvanica	32	1		7						
Quercus lyrata	2	1		3	2	3				
Others*	108	5	2	3						
Total	1031	64	48	34	8	10	3	1		

* See Table II-29 for a list of other species present.

trees were prevalent and representatives of these species were the only ones with diameters greater than 40 cm. There were 27 species of trees and shrubs recorded at this site with an average of 4.0 plants per plot.

Site 5 (Adjacent to Smith Break)

Site 5, located adjacent to Smith Break (Fig. II-07), contained a fairly open forest with little underbrush. Trees were generally scattered as indicated by the presence of 1.95 individuals per plot. In addition, the study plots transected a slough as evidenced by the occurrence of water hickory (*Carya aquatica*), water locust (*Gleditsia aquatica*), swamp privet (*Forestiera acuminata*), and water elm (*Planera aquatica*).

Dominant trees in the area were cedar elm, willow oak, hawthorn and honey locust (*Gleditsia triacanthos*) (Table II-31). Trees of overcup oak and Texas sugarberry were also prevalent. Willow oak, overcup oak and green ash were the only species with representatives having diameters greater than 50 cm (Table II-32). There were 24 species recorded in plots at this site.

Site 6 (Adjacent to Brushy Lake)

Of the sites studied, Site 6 is nearest the Trinity River (Fig. II-07). The topography of Site 6 is generally flat with an occasional slough. The area was fairly evenly dominated by hawthorn, southern red oak, cedar elm, water oak (*Quercus nigra*) and honey locust (Table II-33). Trees of winged-elm (*Ulmus alata*) and Texas sugarberry were also occasionally encountered. Trees were generally less than 50 cm in diameter (Table II-34). Thirty species were recorded at this site and there was an average of 2.62 trees or shrubs per plot.

Combined Swamp Sites (Sites 1 and 2)

When data from The Break and Smith Break were combined, tupelo, bald cypress, Carolina ash and sweet-spire emerged as dominants (Table II-35). Tupelo and bald cypress were by far the dominant species in both areas. In Smith Break, however, Carolina ash and sweet-spire were lacking and water elm and common buttonbush replaced these species as subdominants (Tables II- 23 and II-25). There were a total of 29 species recorded in both areas.

Table II-31. Frequency, density and dominance data for plant species located at Site 5 adjacent to and north of Smith Break.

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Ulmus crassifolia	26.3	18.5	0.36	18.5	23.8	60.8
Quercus Phellos	14.0	9.9	0.14	7.2	41.3	58.4
Crataegus spp.	25.0	17.6	0.46	23.6	1.2	42.4
Gleditsia triacanthos	20.0	14.1	0.32	16.6	2.8	33.5
Quercus lyrata	6.7	4.7	0.08	3.9	11.4	20.0
Celtis laevigata	9.3	6.6	0.10	5.0	4.7	16.3
Ilex decidua	9.7	6.8	0.13	6.[illegible]	0.5	13.[illegible]
Carya aquatica	6.7	4.7	0.07	3.6	2.6	10.9
Fraxinus pensylvanica	4.3	3.1	0.05	2.4	4.4	9.9
Diospyros virginiana	5.0	3.5	0.06	2.9	0.1	6.5
Others**		10.3	0.18	9.[illegible]	7.3	27.2
Total	----	99.8	1.95	99.8	100.1	299.7

* Sum of relative frequency, relative density, and relative dominance.

** Other species present listed in decreasing order of importance values: *Crataegus Marshallii*, *Quercus falcata*, *Carya illinoinensis*, *Gleditsia aquatica*, *Quercus nigra*, *Ulmus* spp. (includes *U. americana* and *U. rubra*), *Morus rubra*, *Ulmus alata*, *Crataegus spathulata*, *Liquidambar Sytraciflua*, *Quercus Prinus*, *Forestiera acuminata*, *Planera aquatica*, *Sesbania Drummondii*.

Table II-32. Size classes (dbh) of plant species located at Site 5 adjacent to and north of Smith Break.

Species	Size Classes (cm)									
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Ulmus crassifolia	50	22	23	10	3					
Quercus Phellos	1	5	9	14	3	6	3	1		
Crataegus spp.	135	2	1							
Gleditsia triacanthos	87	7	2	1						
Quercus lyrata	2	11	3	4	1	1	1			
Celtis laevigata	13	6	10							
Ilex decidua	38									
Carya aquatica	9	11	1							
Fraxinus pensylvanica	6	3	2	2		1				
Diospyros virginiana	16	1								
Others*	41	10	1	2	3					
Total	398	78	52	33	10	8	4	1		

* See Table II-31 for a list of other species present.

Table II-33. Frequency, density and dominance data for plant species located at Site 6 near the Trinity River west of Brushy Lake.

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Crataegus spp.	27.0	14.4	0.50	19.2	0.7	34.3
Quercus falcata	8.0	4.3	0.09	3.3	24.3	31.9
Ulmus crassifolia	23.7	12.6	0.36	13.7	4.5	30.8
Quercus nigra	9.7	5.2	0.10	3.9	19.3	28.4
Gleditsia triacanthos	24.0	12.8	0.35	13.5	1.6	27.9
Ulmus alata	16.7	8.9	0.26	9.9	4.5	23.3
Celtis laevigata	12.3	6.6	0.14	5.2	9.9	21.7
Crataegus spathulata	15.7	8.3	0.22	8.3	0.2	16.8
Quercus velutina	4.0	2.1	0.06	2.2	6.4	10.7
Ilex decidua	7.7	4.1	0.10	3.8	0.6	8.5
Others**		20.9	0.44	17.0	28.0	65.9
Total	----	100.2	2.62	100.0	100.0	300.2

* Sum of relative frequency, relative density, and relative dominance.

** Other species present listed in decreasing order of importance values: *Quercus sinuata*, *Fraxinus pensylvanica*, *Ulmus* spp. (includes *U. americana* and *U. rubra*), *Quercus Prinus*, *Crataegus Marshallii*, *Quercus lyrata*, *Fraxinus americana*, *Tilia americana* (includes *T. caroliniana* and *T. floridana*), *Quercus Phellos*, *Planera aquatica*, *Cephalanthus occidentalis*, *Zanthoxylum Clava-Herculis*, *Bumelia lanuginosa*, *Liquidambar Styraciflua*, *Cornus racemosa*, *Diospyros virginiana*, *Carya illinoinensis*, *Carya aquatica*, *Morus rubra*, *Ilex vomitoria*.

Table II-34. Size classes (dbh) of plant species located at Site 6 near the Trinity River west of Brushy Lake.

Species	Size Classes (cm)									
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Crataegus spp.	150	1								
Quercus falcata	1	4	2	7	6	3	1	2		
Ulmus crassifolia	91	10	6	1						
Quercus nigra		3	11	7	8	2				
Gleditsia triacanthos	99	6	1							
Ulmus alata	52	25	1							
Celtis laevigata	6	16	16	3						
Crataegus spathulata	65									
Quercus velutina		4	8	4	1					
Ilex decidua	27	1	2							
Others*	65	27	29	8	4					
Total	556	97	76	30	19	5	1	2		

* See Table II-33 for a list of other species present.

Table II-35. Summary of frequency, density, and dominance data for plant species located in Sites 1 and 2 (The Break and Smith Break).

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Nyssa aquatica	58.9	32.9	1.66	45.2	72.1	150.2
Taxodium distichum	31.4	17.6	0.44	11.9	24.8	54.3
Fraxinus caroliniana	19.8	11.1	0.33	9.1	0.4	20.6
Itea virginica	15.3	8.6	0.38	10.4	**	19.0
Planera aquatica	15.9	8.9	0.22	6.0	0.5	15.4
Acer rubrum	9.5	5.3	0.24	6.5	0.6	12.4
Cephalanthus occidentalis	7.0	3.9	0.11	3.1	0.1	7.1
Fraxinus pensylvanica	4.5	2.5	0.07	1.8	0.2	4.5
Liquidambar Styraciflua	2.2	1.2	0.03	0.8	0.8	2.8
Quercus lyrata	2.4	1.4	0.03	0.7	0.1	2.2
Others***		6.8	0.14	4.2	0.3	11.3
Total	----	100.2	3.65	99.7	99.9	299.8

* Sum of relative frequency, relative density, and relative dominance.

** Value less than 0.1.

*** Other species present listed in order of decreasing importance values: _Carya aquatica_, _Sesbania Drummondii_, _Forestiera acuminata_, _Ulmus_ spp. (includes _U. americana_ and _U. rubra_), _Gleditsia aquatica_, _Celtis laevigata_, _Quercus Phellos_, _Cornus racemosa_, _Quercus falcata_, _Diospyros virginiana_, _Callicarpa americana_, _Carpinus caroliniana_, _Ilex decidua_, _Ilex opaca_, _Ilex vomitoria_, Quercus nigra, Quercus Shumardii, _Ulmus crassifolia_. _Sabal minor_, not included in column totals, had a density of 0.05 individuals per plot.

Combined Terrestrial Sites (Sites 3, 4, 5, and 6)

The overall dominant species within the land communities studied were hawthorn, cedar elm and honey locust. Willow oak, deciduous holly, Texas sugarberry, water oak and southern red oak were also prevalent (Table II-36). Cedar elm and hawthorn were among the top three dominants in three of the study sites. Honey locust, while not among the first three dominants on any site, was nevertheless a significant component of all four plant communities (Tables II-27, II-29, II-31, and II-33). Fifty-two woody species were found in the terrestrial communities studied.

STUDY AREA 9

Introduction

The objective of this phase of the study was to characterize the woody vegetation associated with the Tanner Bayou and Capers Ridge areas (Fig. II-08). Field work was accomplished during the fall of 1972. The study area was situated within Liberty County in southeast Texas near the junction of State Highway 162 and the Trinity River. The study area was located on the west side of the river (Fig. II-08).

Topographically, the study area is generally flat. Several lakes, swamps, and sloughs were present, the most obvious of which were Gaylor Lake and Mud Lake. The area is drained by Tanner Bayou, Little Bayou and Gaylor Creek. The river terrace extends from near Gaylor Lake southward to Capers Ridge where it projects eastward along Capers Ridge almost to the Trinity River.

Geologically, most of the study area is composed of Alluvium deposits of Recent origin. Marginal elevated areas were part of the Deweyville Formation whereas outcrops of the Beaumont Formation comprised the crest of Capers Ridge. The Deweyville Formation is of Recent or Pleistocene origin while the Beaumont Formation is of Pleistocene origin. All deposits are within the Quaternary Period.

Soil surveys were incomplete in regard to the study area and, as a result, some extrapolations have been made. Based on available information, there appeared to be four major soil types present. These were Kaufman clay, Forestdale silt loam, Acadia silt loam and Tuckerman loam. The most extensive soil was the Kaufman clay. The Kaufman clay soils occupy the somewhat poorly drained bottomland

Table II-36. Summary of frequency, density, and dominance data for plant species located in Sites 3, 4, 5, and 6 (land areas associated with The Break, Smith Break, and Brushy Lake).

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Crataegus spp.	27.0	14.1	0.56	20.3	1.2	35.6
Ulmus crassifolia	20.6	10.8	0.29	10.3	13.4	34.5
Gleditsia triacanthos	21.5	11.3	0.34	12.2	2.9	26.4
Quercus Phellos	5.8	3.0	0.06	2.3	14.7	20,0
Ilex decidua	17.0	8.9	0.26	9.5	0.9	19.3
Celtis laevigata	10.8	5.6	0.13	4.6	8.9	19.1
Quercus nigra	6.0	3.1	0.06	2.3	11.1	16.5
Quercus falcata	5.2	2.7	0.06	2.1	10.3	15.1
Fraxinus pensylvanica	5.8	3.1	0.06	2.2	4.4	9.7
Ulmus alata	7.3	3.8	0.10	3.8	1.9	9.5
Others**		33.1	0.84	30.0	29.8	92.9
Total	----	99.5	2.76	99.6	99.5	298.6

* Sum of relative frequency, relative density, and relative dominance.

** Other species present listed in order of decreasing importance values: Diospyros virginiana, Quercus velutina, Quercus lyrata, Liquidambar Styraciflua, Ulmus spp. (includes U americana and U rubra), Carya illinoinensis, Crataegus spathulata, Carya aquatica, Quercus Prinus, Halesia diptera, Ilex vomitoria, Crataegus Marshallii, Callicarpa americana, Carpinus caroliniana, Quercus sinuata, Morus rubra, Ilex opaca, Sambucus canadensis, Viburnum dentatum, Cornus racemosa, Fraxinus americana, Tilia americana (includes T caroliniana and T floridiana), Nyssa sylvatica, Planera aquatica, Gleditsia aquatica, Bumelia lanuginosa, Cephalanthus occidentalis, Zanthoxylum Clava-Herculis, Cercis canadensis, Halesia carolina, Taxodium distichum, Sapindus Saponaria, Aralia spinosa, Carya cordiformis, Citrus trifoliata, Forestiera acuminata, Pinus taeda, Prunus mexicana, Quercus Shumardii, Sesbania Drummondii. Sabal minor, not included in column totals, had a density of 1.33 individuals per plot.

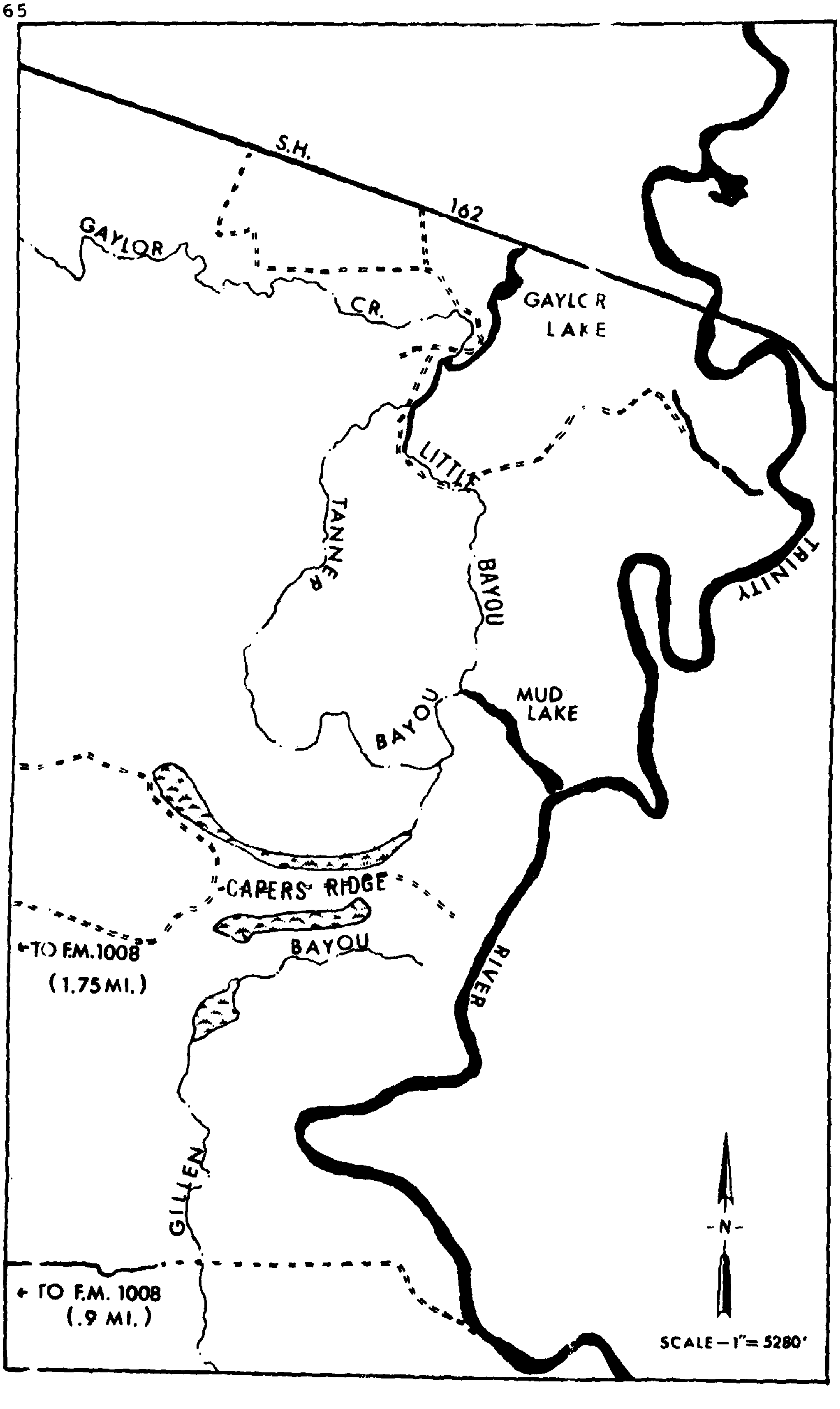


Figure II-08. Showing the study area in relation to the Trinity River.

floodplain areas. They are suited primarily for pond reservoir areas and woodland and wetland wildlife (U.S. Department of Agriculture, unpublished data). They have some potential for grassland. The Forestdale silt loam soils were slightly elevated above and generally bordering the Kaufman clay soils. Drainage is slow and ponding occurs in depressions. They are poorly suited for dwellings but offer a fair potential for cropland and grassland. Woodland production is favorable. The most elevated sites in the study area contained Acadia silt loam soils. The Acadia soils are highly productive for woodland, suited for wildlife but exhibit only a fair potential for cropland and pasture. They are poorly suited for dwellings. The Tuckerman soils occupy nearly level concave areas and are generally poorly drained and ponded. They are poorly suited for dwellings, general recreation use, cropland or grassland but are suited for pond reservoir areas and wetland wildlife.

The vegetation of the study area was mostly bottomland hardwood forest. Bordering, higher elevated areas supported some pines and other upland species. Cleared areas were few and generally associated with roads and pipelines. Cattle grazed most of the area and past logging was evident.

Land Use

Liberty County had a population of 33,014 in 1970, about half of which resided in the county's four largest towns (*Texas Almanac*, 1971). The economy is based on agribusiness, varied light industry, tourism, and employment in the Houston metropolitan area. Oil, gas, sulfur, sand and gravel are produced within the county. Agriculture, based mainly on rice and cattle, contributes $15 million annually to the economy. Sales of timber within the county total about $2 million annually.

With no National Forests or other reserved land within its boundaries, less than one-thirtieth of Liberty County's 756,480 acres was classified in 1967 as urban and other non-commercial area (Table II-37) (Liberty County Conservation Needs Committee, 1970). Of the commercial land area, 60% is forested. Between 1958 and 1967, the acreage of forest within the county increased slightly, probably as a result of a change in the boundary with Harris County which increased the total land area of Liberty County.

Table II-37. Liberty County land area (in acres).
(from Liberty County Conservation Needs Committee, 1970.)

Land Use	1958	1967
Total land area*	750,590	756,480
Less: Federal non-cropland	0	0
Less: Urban and built-up	24,366	24,666
Less: Small water areas	6	136
Total non-commercial area	24,372	24,802
Total commercial farm and forest area	726,218	731,678
Cropland	164,293	144,465
Pasture**	110,462	125,539
Forest	450,280	453,600
Other land	1,183	8,074

* Different acreage because of boundary change between Liberty and Harris counties.

** Includes 18,349 acres of open range in 1958, none in 1967.

Of the approximately 270,000 acres devoted to agriculture about 54% is in cropland. In 1958, cropland acreage was predicted to increase roughly 9,000 acres by 1975, but by 1967 had declined 20,000 acres (Liberty County Conservation Needs Committee, 1958 and 1970). Pastureland, predicted to increase only 4,000 acres between 1958 and 1975, had already jumped 15,000 acres by 1967. The classification "other land", including building sites, lawns, barnyards, farm roads, etc., was expected to increase from about 1,200 acres in 1958 to slightly less than 1,800 acres in 1975. Land devoted to these uses, however, had increased spectacularly to just under 8,100 acres by 1967.

While it will remain an important major land use, cropland acreage will likely continue to decrease in the near future. Marginal and fallow cropland will probably be converted to improved pasture, a pattern common to all of East Texas. It appears that forests will decline, generally being converted to improved pasture and weekend home sites.

Although the 8,074 acres devoted to "other land" uses in 1967 was hardly more than 1% of the county's area, its jump from only 1,183 acres in 1958 was unexpected, and the trend visibly continues. The boom in vacation and weekend home construction, with attendent roads and other facilites, accounts for most of the increase. Larger and more elaborate developments will continue to draw permanent residents willing to commute to jobs in Houston and Beaumont. The concentration of new housing developments on the limited amount of land along the Trinity River and nearby oxbow lakes magnifies the impact beyond that indicated by acreage figures alone.

Development has also begun in the Tanner Bayou-Capers Ridge vicinity. Weekend houses have already been built on Gaylor Lake. A large, expensive development just across Highway 162 is the fastest growing in Liberty County. Across the river from Capers Ridge is Knight's Forest, another large development. In addition, construction has been started on a road which will eventually parallel and open for development a portion of the riverfront to the east of Gaylor Lake.

The county's appraisal of potential for outdoor recreational development (Anonymous, 1966) rates it medium-high for vacation cabins, cottages, and homesites. It has high potential for picnic and field sport use, as well as some appeal for campers. Despite poorly drained soils,

terrain too flat for water impoundments, frequent rain and the abundance of mosquites, the heavily wooded scenery along the Trinity River within an hour's drive of Houston and Beaumont appeals to outdoor recreation seekers.

Methods and Procedures

Seven study sites were selected within the Tanner Bayou and Capers Ridge areas (Figs. II-09, II-10, and II-11). The more undisturbed plant communities were selected representing variable vegetative types present. Transects were positioned within each study site as indicated in Figures II-09, II-10, and II-11. A total of 1,700 plots ($5m^2$) were analyzed. Three hundred plots were analyzed in each study site with the exceptions of Site 6 (100 plots) and Site 7 (100 plots).

Description of Study Sites

Sites 1 and 2 were located near the junction of Highway 162 and the Trinity River (Fig. II-09). These sites were on Kaufman clay soils and were generally flat. Site 3 was situated north of a slough near the river (Fig. II-09). The topography was flat to slightly rolling and the soils were Kaufman clay. Site 4 was located in a vegetational ecotone associated with a terrace area west of Gaylor Lake (Fig. II-10). Topography varied from steeply sloping ravines to generally flat conditions. Soils present included Forestdale silt loam, Acadia silt loam and Kaufman clay. Site 5 comprised transects in association with Capers Ridge (Fig. II-11). One transect followed the ridge whereas the other two transects were on north- and south-facing slopes respectively. The soils were probably Forestdale silt loam and Acadia silt loam. The ridge gently slopes from an elevation of 99 feet to an elevation of 35 feet. Site 6 was a flat bottomland at the north base of Capers Ridge and Site 7 was a swamp at the foot of the south slope (Fig. II-11). Site 6 was probably situated on the Kaufman clay soil and Site 7 on the Tuckerman loam soil.

Results

Site 1

The predominant woody species at Site 1 based on importance value, were Texas sugarberry *(Celtis laevigata)* and pecan *(Carya illinoinensis)* (Table II-38). Both were well distributed and displayed good size class distribution (Table II-39). Dogwood *(Cornus racemosa)*, swamp privet *(Forestiera acuminata)*, and water elm *(Planera aquatica)*

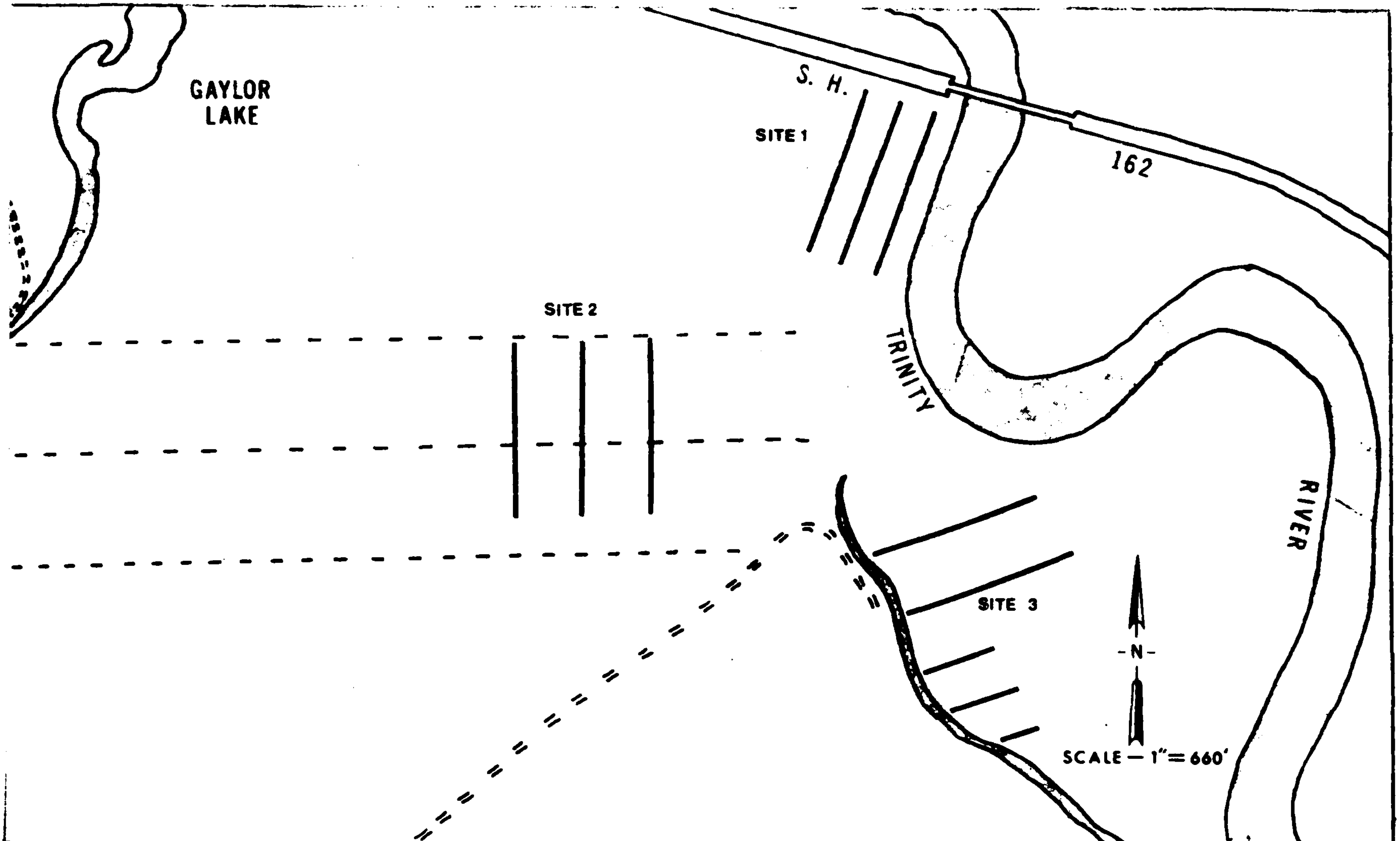


Figure II-09. Showing sites 1,2, and 3 and the position of transects within these sites.

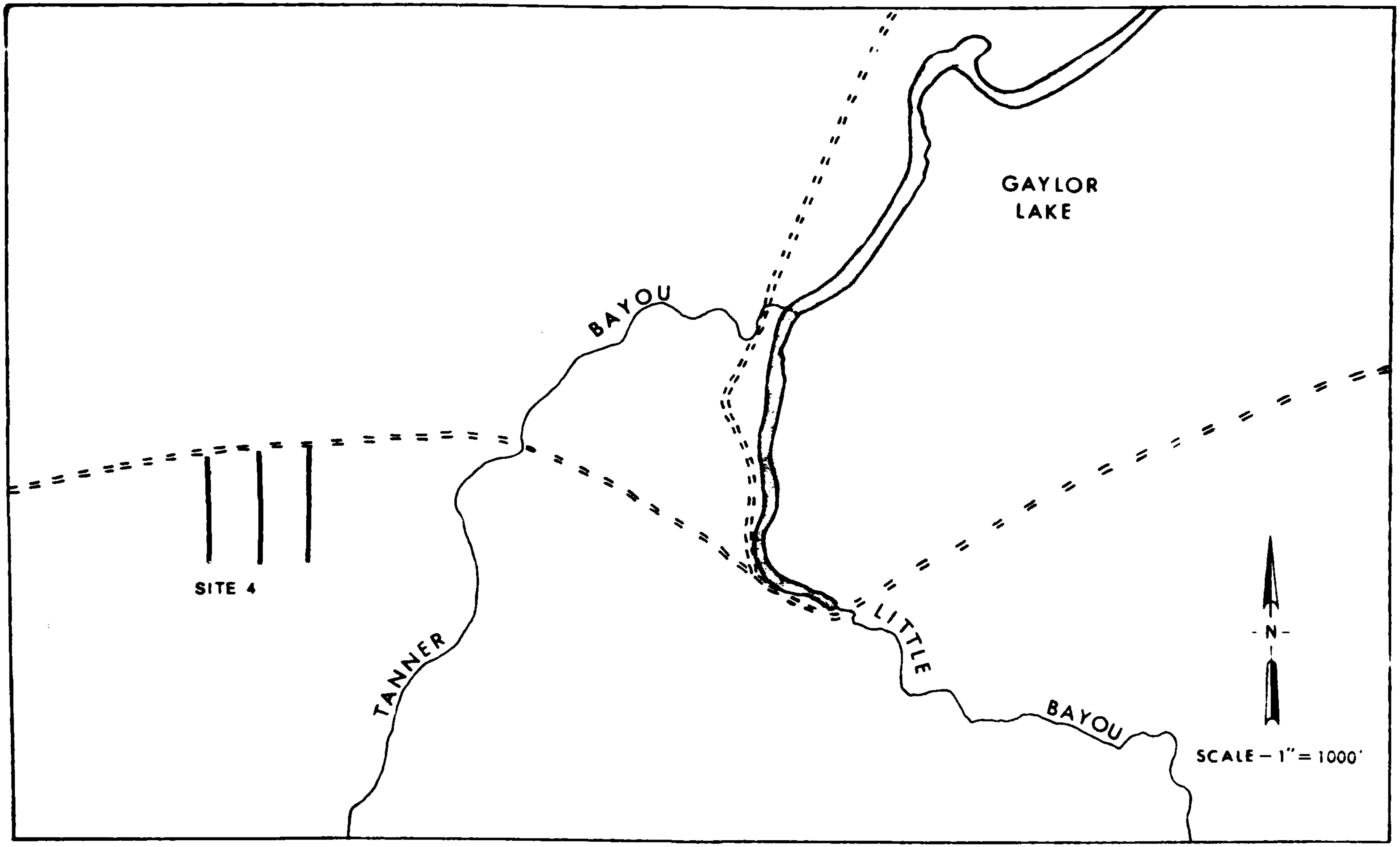


Figure II-10. Showing site 4 and positions of transects within that site.

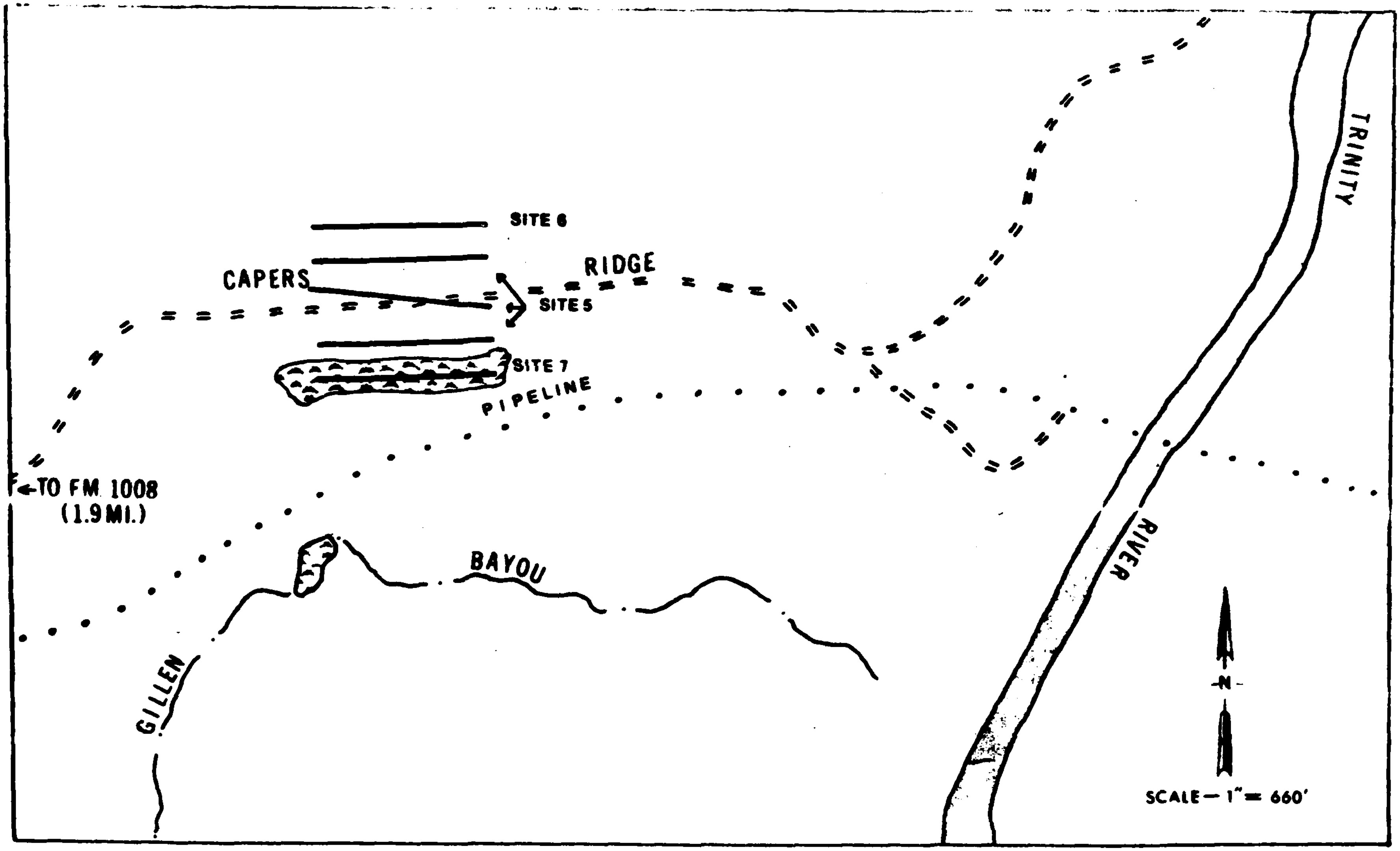


Figure II-11. Showing sites 5,6, and 7 and the position of transects within these sites.

were also prevalent. Stem size (dbh) for these species, however, was generally between 1 and 20 cm. Larger trees of sweetgum (*Liquidambar Styraciflua*) and sycamore (*Platanus occidentalis*) were frequently observed (Table II-39). There were 27 species of woody plants with dbh of 1 cm or greater recorded within this study site.

Site 2

Cedar elm (*Ulmus crassifolia*), Texas sugarberry and water oak (*Quercus nigra*) were the principal woody species at Site 2 (Table II-40). Other associated dominant species were winged-elm (*Ulmus alata*), deciduous holly (*Ilex decidua*) and bastard oak (*Quercus sinuata*). The forest at Site 2 was generally composed of trees with dbh less than 40 cm (Table II-41). Only occasionally were larger trees observed and these were usually representatives of Texas sugarberry, water oak, bottomland post oak and southern red oak (*Quercus falcata*). There were 28 species of woody plants recorded at Site 2.

Site 3

The overstory woody vegetation in Site 3 consisted chiefly of Texas sugarberry and sweetgum (Table II-42). Trees of these species ranged up to 60 cm in diameter (Table II-43). Pecan, bald cypress (*Taxodium distichum*) and water oak were also prevalent and showed good size class distribution. The largest trees recorded were those of water oak. Other dominant species including deciduous holly, dogwood, cedar elm, winged-elm and elm (*Ulmus* spp.) were generally small in size with most plants representative of the 1-10 cm size class (Table II-43). A total of 37 species occurred at Site 3.

Site 4

There were 54 species recorded at Site 4. The more varied topography of this area is the likely cause of its greater species diversity. Two transects were run on a slope and one on a flat bottomland. The upper part of the slope was dominated by yaupon (*Ilex vomitoria*), sweetgum and eastern hophornbeam (*Ostrya virginiana*). Associated prevalent species were American beautyberry (*Callicarpa americana*), blue beech (*Carpinus caroliniana*), southern magnolia (*Magnolia grandiflora*) and loblolly pine (*Pinus taeda*). The middle-slope area was composed primarily of blue beech. Other principal species were sweetgum, southern magnolia, American beautyberry, yaupon, eastern

Table II-38. Frequency, density and dominance data for plant species located in the Tanner Bayou area near Highway 162, Site 1.

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Celtis laevigata	35.3	21.9	0.53	19.7	22.2	63.8
Carya illinoinensis	26.3	16.4	0.32	11.9	34.2	62.5
Cornus racemosa	15.0	9.3	0.30	11.1	2.4	22.8
Forestiera acuminata	12.0	7.5	0.27	10.2	2.8	20.5
Planera aquatica	7.7	4.8	0.31	11.5	2.0	18.3
Liquidambar Styraciflua	6.0	3.7	0.09	3.5	9.5	16.7
Ilex decidua	10.7	6.6	0.19	7.1	1.0	14.7
Crataegus spp.	11.0	6.8	0.15	5.5	0.5	12.8
Ulmus crassifolia	10.0	6.2	0.14	5.1	1.5	12.8
Platanus occidentalis	2.7	1.7	0.03	1.2	8.8	11.7
Others**		15.1	0.34	12.6	15.0	42.7
Total	----	100.0	2.67	99.4	99.9	299.3

* Sum of relative frequency, relative density and relative dominance.

** Other species present listed in order of decreasing importance values: Fraxinus pensylvanica, Ulmus spp. (includes U. americana and U. rubra), Sambucus canadensis, Acer Negundo, Diospyros virginiana, Quercus velutina, Gleditsia triacanthos, Quercus lyrata, Quercus nigra, Quercus falcata, Ulmus alata, Taxodium distichum, Cephalanthus occidentalis, Tilia americana (includes T. caroliniana and T. floridana), Ostrya virginiana, Bumelia lanuginosa, Morus rubra.

Table II-39. Size classes (dbh) of plant species located in the Tanner Bayou area near Highway 162, Site 1.

Species	Size Classes (cm)									
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Celtis laevigata	29	89	33	6	1					
Carya illinoinensis	8	28	25	22	10	2				
Cornus racemosa	75	13	1							
Forestiera acuminata	73	9								
Planera aquatica	84	8								
Liquidambar Styraciflua	5	5	11	3	2	2				
Ilex decidua	55	2								
Crataegus spp.	40	4								
Ulmus crassifolia	32	7	2							
Platanus occidentalis		1		4	3		2			
Others*	80	13	2	3	4	1	1	1		
Total	481	179	74	38	20	5	3	1		

* See Table II-38 for a list of other species present.

Table II-40. Frequency, density and dominance data for plant species located in the Tanner Bayou area near Highway 162, Site 2.

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Ulmus crassifolia	55.7	15.0	1.28	18.8	8.2	42.0
Celtis laevigata	40.3	10.8	0.76	11.1	18.3	40.2
Quercus nigra	23.7	6.4	0.34	5.0	23.8	35.2
Ulmus alata	36.7	9.9	0.60	8.8	5.0	23.7
Ilex decidua	32.7	8.8	0.64	9.4	2.4	20.6
Quercus sinuata	13.7	3.7	0.22	3.3	9.6	16.6
Crataegus spp.	22.0	5.9	0.50	7.4	0.7	14.0
Quercus falcata	12.0	3.2	0.18	2.7	8.0	13.9
Gleditsia triacanthos	19.0	5.1	0.28	4.1	3.1	12.3
Crataegus marshallii	21.0	5.6	0.37	5.5	0.5	11.6
Others**		25.4	1.64	23.8	20.2	69.4
Total	----	99.8	6.81	99.9	99.8	299.5

* Sum of relative frequency, relative density and relative dominance.

** Other species present listed in order of decreasing importance values: *Arundinaria gigantea*, *Fraxinus americana*, *Fraxinus pensylvanica*, *Ulmus spp.* (includes *U. americana* and *U. rubra*), *Sapindus Saponaria*, *Ilex vomitoria*, *Bumelia lanuginosa*, *Quercus Phellos*, *Quercus lyrata*, *Diospyros virginiana*, *Cornus racemosa*, *Quercus velutina*, *Carya illinoinensis*, *Morus rubra*, *Prunus caroliniana*, *Carya texana*, *Tilia americana*, (includes *T. caroliniana* and *T. floridana*), *Crataegus spathulata*.

Table II-41. Size classes (dbh) of plant species located in the Tanner Bayou area near highway 162, Site 2.

Species	Size Classes (cm)									
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Ulmus crassifolia	352	19	8	4						
Celtis laevigata	162	27	29	8		1				
Quercus nigra	35	30	15	15	5	1				
Ulmus alata	148	26	5							
Ilex decidua	189	2								
Quercus sinuata	45	11	5	4		1		1		
Crataegus spp.	148	2								
Quercus falcata	35	7	6	5	2					
Gleditsia triacanthos	73	5	5	1						
Crataegus Marshallii	112									
Others**	423	35	18	11	4					
Total	1722	164	91	48	11	3		1		

** See Table II-40 for a list of other species present.

Table II-42. Frequency, density and dominance data for plant species located in the Tanner Bayou area near Highway 162, Site 3.

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Celtis laevigata	33.3	16.8	0.44	15.5	24.6	56.9
Liquidambar Styraciflua	27.3	13.8	0.47	16.5	16.8	47.1
Carya illinoinensis	17.3	8.7	0.22	7.7	13.7	30.1
Ilex decidua	25.3	12.8	0.33	11.8	0.8	25.4
Quercus nigra	6.0	3.0	0.06	2.1	12.6	17.7
Cornus racemosa	10.0	5.0	0.19	6.7	1.1	12.8
Taxodium distichum	4.0	2.0	0.07	2.4	7.4	11.8
Ulmus crassifolia	10.3	5.2	0.12	4.1	1.0	10.3
Ulmus spp. **	8.7	4.4	0.11	4.0	1.5	9.9
Ulmus alata	9.0	4.5	0.13	4.5	0.8	9.8
Others ***		23.8	0.68	24.7	19.8	68.3
Total	----	100.0	2.82	100.0	100.1	300.1

* Sum of relative frequency, relative density and relative dominance.

** Includes U. americana and U. rubra.

*** Other species present listed in order of decreasing importance values: Crataegus spp., Fraxinus pensylvanica, Planera aquatica, Quercus velutina, Diospyros virginiana, Cephalanthus occidentalis, Arundinaria gigantea, Ilex opaca, Quercus lyrata, Tilia americana (includes T. caroliniana and T. floridana), Carya aquatica, Quercus falcata, Fraxinus americana, Morus rubra, Bumelia lanuginosa, Quercus similis, Gleditsia aquatica, Acer Negundo, Quercus Prinus, Salix nigra, Gleditsia aquatica, Forestiera acuminata, Nyssa sylvatica, Zanthoxylum Clava-Herculis, Crataegus spathulata, Callicarpa [illegible]icana, Sambucus canadensis.

Table II-43. Size classes (dbh) of plant species located in the Tanner Bayou area near Highway 162, Site 3.

Species	Size Classes (cm)									
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Celtis laevigata	49	38	34	11	7	2				
Liquidambar Styraciflua	67	36	26	9	2					
Carya illinoinensis	21	22	10	6	4	2				
Ilex decidua	100									
Quercus nigra	9	2	2	1		1	1		2	
Cornus racemosa	52	5								
Taxodium distichum	5	4	3	5	1	2				
Ulmus crassifolia	34				1					
Ulmus spp.*	33					1				
Ulmus alata	32	5	1							
Others**	156	22	14	10	5	3				
Total	558	134	90	42	20	11	1		2	

* Includes *U. Americana* and *U. rubra* .

** See Table II-42 for a list of other species present.

hophornbeam, winged-elm and southern red oak. The dominant tree species in the flat bottomland area were blue beech, cedar elm, chestnut oak (Quercus Prinus) and sweetgum. Other prevalent species included water oak, Texas sugarberry, southern red oak, red maple (Acer rubrum) and honey locust (Gleditsia triacanthos).

Table II-44 is a summary of the slope and bottomland transect results at Site 4 and indicates that blue beech, sweetgum, yaupon and southern magnolia were the overall dominants. Eastern hophornbeam, American beautyberry, and cedar elm were also prevalent. Tree diameters were generally within the 1-10 cm size class (Table II-45). Large trees of sweetgum, southern magnolia, southern red oak, chestnut oak, water oak and loblolly pine were occasionally encountered.

Site 5

The predominant species along the crest of Capers Ridge was yaupon. Trees of sweetgum, Texas sugarberry, and winged-elm were also quite abundant. American beautyberry, which is a shrub, was also frequently encountered. The north slope of Capers Ridge contained a preponderance of giant cane (Arundinaria gigantea). Sweetgum was also dominant. Of lesser abundance was water oak, Texas sugarberry, winged-elm and American beautyberry. Devil's-walking-stick (Aralia spinosa), water oak and black walnut (Juglans nigra) were occasionally observed. Yaupon was the dominant woody species on the south slope, and along with American beautyberry, dominated the shrub layer. Prevalent tree species comprising the mid- and upper-layers were sweetgum, Texas sugarberry and winged-elm.

The overall dominants of Site 5 as summarized in Table II-46 were yaupon, sweetgum, giant cane, and Texas sugarberry. Winged-elm, water oak, and American beautyberry were prevalent but less frequently encountered. Most woody plants on Capers Ridge had stem diameters between 1 and 10 cm (Table II-47). Occasionally, however, large trees of sweetgum, Texas sugarberry, water oak, black walnut, and sycamore (Platanus occidentalis) were observed. There was a good species diversity at Site 5 with 45 woody tree and shrub species being recorded.

Site 6

The bottomland vegetation at Site 6 consisted chiefly of overcup oak (Quercus lyrata), green ash (Fraxinus

Table II-44. Frequency, density and dominance data for plant species located in the Tanner Bayou area west of Gaylor Lake, Site 4.

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Carpinus caroliniana	59.0	13.6	1.61	18.7	10.7	43.0
Liquidambar Styraciflua	34.7	8.0	0.57	6.7	17.7	32.4
Ilex vomitoria	40.0	9.2	1.24	14.4	1.3	24.9
Magnolia grandiflora	6.0	1.4	0.07	0.9	18.6	20.9
Ostrya virginiana	26.3	6.1	0.54	6.2	3.7	16.0
Callicarpa americana	31.0	7.1	0.60	7.0	0.2	14.3
Ulmus crassifolia	22.3	5.1	0.62	7.2	0.6	12.9
Quercus falcata	15.7	3.6	0.21	2.4	5.9	11.9
Celtis laevigata	24.0	5.5	0.51	6.0	0.4	11.9
Quercus Prinus	7.3	1.7	0.08	0.9	9.1	11.7
Others**		38.7	2.56	29.6	31.9	100.2
Total	----	100.0	8.61	100.0	100.1	300.1

* Sum of relative frequency, relative density, and relative dominance.

** Other species present listed in order of decreasing importance values: *Ulmus alata*, *Quercus nigra*, *Pinus taeda*, *Arundinaria gigantea*, *Crataegus* spp., *Sambucus canadensis*, *Ilex decidua*, *Juglans nigra*, *Ulmus* spp. (includes *U. americana* and *U. rubra*), *Fraxinus pensylvanica*, *Ilex opaca*, *Fraxinus americana*, *Sassafras albidum*, *Crataegus Marshallii*, *Carya aquatica*, *Morus rubra*, *Gleditsia triacanthos*, *Quercus velutina*, *Quercus alba*, *Tilia americana* (includes *T. caroliniana* and *T. floridana*), *Nyssa sylvatica*, *Cornus florida*, *Diospyros virginiana*, *Carya tomentosa*, *Quercus lyrata*, *Quercus Phellos*, *Zanthoxylum Clava-Herculis*, *Forestiera ligustrina*, *Crataegus spathulata*, *Viburnum dentatum*, *Vaccinium arboreum*, *Cornus racemosa*, *Bumelia lanuginosa*, *Aralia spinosa*, *Platanus occidentalis*, *Quercus similis*, *Taxodium distichum*, *Rhus copallina*, *Forestiera acuminata*, *Cornus Drummondii*, *Carya illinoinensis*, *Persea Borbonia*, *Acer rubrum*, *Symplocos tinctoria*.

Table II-45. Size classes (dbh) of plant species located in the Tanner Bayou area west of Gaylor Lake, Site 4.

Species	Size Classes (cm)									
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Carpinus caroliniana	426	34	21	1						
Liquidambar Styraciflua	109	28	18	10	7					
Ilex vomitoria	351									
Magnolia grandiflora	3		7	3	5	2	2			
Ostrya virginiana	136	19	5	1						
Callicarpa americana	180									
Ulmus crassifolia	182	4								
Quercus falcata	48	7	2	1	2	2				
Celtis laevigata	154									
Quercus Prinus	18				1	2	2	1		
Others*	727	23	14	12	6	6	2		1	
Total	2334	115	67	28	21	12	6	1	1	

* See Table II-44 for a list of other species present.

Table II-46. Frequency, density and dominance data for plant species located on Capers Ridge, Site 5.

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Ilex vomitoria	66.0	14.1	2.32	20.6	9.1	43.8
Liquidambar Styraciflua	34.3	7.3	0.63	5.6	28.9	41.8
Arundinaria gigantea	24.0	5.1	2.48	22.1	1.0	28.2
Celtis laevigata	47.3	10.1	0.89	7.9	8.8	26.8
Ulmus alata	42.3	9.0	0.88	7.9	2.5	19.4
Quercus nigra	22.0	4.7	0.34	3.0	10.4	18.1
Callicarpa americana	43.3	9.2	0.85	7.6	0.4	17.2
Juglans nigra	10.0	2.1	0.12	1.1	5.9	9.1
Ulmus spp.**	20.0	4.3	0.25	2.2	1.6	8.1
Aralia spinosa	14.7	3.1	0.39	3.4	1.4	7.9
Others***		30.7	2.07	18.6	30.2	79.5
Total	----	99.7	11.22	100.0	100.2	299.9

* Sum of relative frequency, relative density, and relative dominance.

** Includes U. americana and U. rubra .

*** Other species present listed in order of decreasing importance values: Fraxinus americana, Sambucus canadensis, Ilex opaca, Bumelia lanuginosa, Quercus falcata, Tilia americana (includes T. caroliniana and T. floridana), Quercus velutina, Quercus Prinus, Platanus occidentalis, Morus rubra, Magnolia grandiflora, Gleditsia triacanthos, Prunus caroliniana, Ilex decidua, Cornus florida, Ulmus crassifolia, Quercus similis, Nyssa sylvatica, Persea Borbonia, Diospyros virginiana, Vaccinium arboreum, Zanthoxylum Clava-Herculis, Viburnum rufidulum, Quercus alba, Fraxinus pensylvanica, Carya illinoinensis, Crataegus spp., Sassafras albidum, Carya aquatica, Prunus serotina, Crataegus spathulata, Prunus mexicana, Rhus copallina, Melia azedarach, Chionanthus virginicus.

Table II-47. Size classes (dbh) of plant species located on Capers Ridge, Site 5.

Species	Size Classes (cm)									
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Ilex vomitoria	687	9								
Liquidambar Styraciflua	111	45	11	11	7	2	2			
Arundinaria gigantea	745									
Celtis laevigata	252	3	2	5	3	1				
Ulmus alata	258	3	3	1						
Quercus nigra	70	18	5	5	2		1			
Callicarpa americana	256									
Juglans nigra	16	7	10	2	1					
Ulmus spp.*	69	4		2						
[illegible]	[illegible]	[illegible]								
Others**	538	53	22	7	4	4	1			
Total	3115	145	53	33	17	7	4			

* Includes *U. americana* and *U. rubra* .
** See Table II-46 for a list of other species present.

pensylvanica), hawthorn (*Crataegus* spp.), water hickory (*Carya aquatica*) and deciduous holly (Table II-48). This site is quite wet during spring and early summer but often is dry during late summer and fall. Twenty-three species were found at Site 6 with representatives generally having stem diameters less than 40 cm (Table II-49).

Site 7

Site 7 was a small shallow persistent swamp with water depths usually less than 2 feet. Green ash was the predominant species in the swamp (Table II-50). Overcup oak and water elm were also frequently recorded. Other associated species were bald cypress and water locust (*Gleditsia aquatica*). Green ash, overcup oak, bald cypress, and water hickory were the only species with representatives having stem diameters greater than 30 cm (Table II-51). Sixteen species were recorded at Site 7.

Table II-48. Frequency, density and dominance data for plant species located in a bottomland area north of Capers Ridge, Site 6.

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Quercus lyrata	40.0	10.2	0.54	7.2	26.1	43.5
Fraxinus pensylvanica	44.0	11.2	1.27	16.8	11.4	39.4
Crataegus spp.	46.0	11.7	1.27	16.8	4.1	32.6
Carya aquatica	21.0	5.4	0.24	3.2	22.4	31.0
Ilex decidua	49.0	12.5	0.94	12.5	1.5	26.5
Ulmus crassifolia	29.0	7.4	0.61	8.1	4.3	19.8
Gleditsia aquatica	13.0	3.3	0.34	4.5	7.2	15.0
Quercus velutina	18.0	4.6	0.27	3.6	5.9	14.1
Cephalanthus occidentalis	21.0	5.4	0.47	6.2	2.3	13.9
Diospyros virginiana	22.0	5.6	0.35	4.6	3.3	13.5
Others**		23.1	1.24	16.2	11.7	51.0
Total	----	100.4	7.54	99.7	100.2	300.3

* Sum of relative frequency, relative density, and relative dominance.

** Other species present listed in order of decreasing importance values: *Celtis laevigata*, *Planera aquatica*, *Amorpha fruticosa*, *Ulmus* spp. (includes *U. americana* and *U. rubra*.) *Taxodium distichum*, *Gleditsia triacanthos*, *Quercus Phellos*, *Forestiera acuminata*, *Pinus taeda*, *Liquidambar Styraciflua*, *Ulmus alata*, *Bumelia lanuginosa*, *Morus rubra*.

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Table II-49. Size classes (dbh) of plant species located in a bottomland area north of Capers Ridge, Site 6.

Species	Size Classes (cm)									
	1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Quercus lyrata	35	5	9	3			2			
Fraxinus pensylvanica	121	1		3	2					
Crataegus spp.	126	1								
Carya aquatica	4	4	6	10						
Ilex decidua	94									
Ulmus crassifolia	58		1	2						
Gleditsia aquatica	19	13	2							
Quercus velutina	20	5		1	1					
Cephalanthus occidentalis	46	1								
Diospyros virginiana	26	9								
Others*	110	9	4		1					
Total	659	48	22	19	4		2			

* See Table II-48 for a list of other species present.

Table II-50. Frequency, density and dominance data for plant species located in a swamp south of Capers Ridge, Site 7.

Species	Frequency %	Relative Frequency %	Density No./Plot	Relative Density %	Relative Dominance %	Importance Value*
Fraxinus pensylvanica	56.0	21.0	1.42	32.8	55.8	109.6
Quercus lyrata	46.0	17.2	0.73	16.9	12.1	46.2
Planera aquatica	50.0	18.7	0.84	19.4	3.3	41.4
Taxodium distichum	19.0	7.1	0.20	4.6	10.4	22.1
Gleditsia aquatica	22.0	8.2	0.26	6.0	6.9	21.1
Quercus velutina	25.0	9.4	0.34	7.9	2.3	19.6
Carya aquatica	11.0	4.1	0.12	2.8	7.5	14.4
Cephalanthus occidentalis	15.0	5.6	0.17	3.9	0.1	9.6
Ulmus spp.**	10.0	3.7	0.11	2.5	0.2	6.4
Diospyros virginiana	4.0	1.5	0.05	1.2	0.2	2.9
Others***		3.5	0.09	1.9	1.1	6.5
Total	----	100.0	4.33	99.9	99.9	299.8

* Sum of relative frequency, relative density, and relative dominance.

** Includes *U. americana* and *U. rubra*.

*** Other species present listed in order of decreasing importance values: *Styrax americana*, *Liquidambar styraciflua*, *Amorpha fruticosa*, *Ilex decidua*, *Quercus falcata*, *Celtis laevigata*.

Table II-51. Size classes (dbh) of plant species located in a swamp south of Capers Ridge, Site 7.

Species	Size Classes (cm) 1-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	>90
Fraxinus pensylvanica	118	2	3	6	10	2	1			
Quercus lyrata	63	5	2	2		1				
Planera aquatica	80	4								
Taxodium distichum	12	6	1							
Gleditsia aquatica	13	8	5					1		
Quercus velutina	28	6								
Carya aquatica	3	6	1	2						
Cephalanthus occidentalis	17									
Ulmus spp.*	11									
Diospyros virginiana	5									
Others**	8		1							
Total	358	37	13	10	10	3	1	1		

* Includes *U. americana* and *U. rubra*.

** See Table II-50 for a list of other species present.

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APPENDIX II

Appendix II-a. Partial checklist of herbaceous species in the Trinity River Basin including annotation of rare and endangered species according to the Rare Plant Study Center (1973) (indicated by *) and the Texas Organization for Endangered Species (1973) (indicated by **).

Common name	Scientific name
Agrimony	Agrimonia parviflora Ait.
Agrimony	Agrimonia rostellata Wallr.
Alfafa	Medicago sativa L.
Amaranth	Amaranthus arenicola I. M. Johnst.
Amaranth	Amaranthus Palmeri Wats.
Amberique bean	Strophostyles helvola (L.) Ell.
American basket-flower	Centaurea americana Nutt.
American germander	Teucrium canadense L.
American nightshade	Solanum americanum Mill.
** American potato bean	Apios americana Medic.
Annual fleabane	Erigeron annuus (L.) Pers.
Annual hairgrass	Aira elegans Gaud.
Annual yellow sweet-clover	Melilotus indicus (L.) All.
Antelope horn	Asclepias viridis Wall.
Arrowhead	Sagittaria graminea Michx.
Arrowhead	Sagittaria montevidensis Cham. & Schlecht
Arrowhead	Sagittaria platyphylla Engelm.

Appendix II-a. Continued.

Common name	Scientific name
Arrowvine	Polygonum sagittatum L.
Aster	Aster Eulae Shinners
Aster	Aster lateriflorus (L.) Britt.
Aster	Aster patens Ait.
Aster	Aster pratensis Raf.
Aster	Aster subulatus Michx.
** Atlantic pigeon wings	Clitoria mariana L.
Autumn bentgrass	Agrostis perennans (Walt.) Tuckerm.
Autumn zephyr-lily	Zephyranthes candida Herb.
Baby blue-eyes	Nemophila microcalyx (Nutt.) Fisch. & Mey.
Baby blue-eyes	Nemophila phacelioides Nutt.
Bahia grass	Paspalum notatum Flugge
Baldwin ironweed	Vernonia Baldwinii Torr.
Balloon-vine	Cardiospermum Halicacabum L.
Barley	Hordeum vulgare L.
Barnyard grass	Echinochloa crusgalli (H.B.K.) Hitchc.
Barnyard grass	Echinochloa crusgallii (L.) Beauv. var. zelayensis (H.B.K.) Hitchc.
Beak rush	Rhynchospora caduca Ell.
Beak rush	Rhynchospora capitellata (Michx.) Vahl
Beak rush	Rhynchospora globularis (Chapm.) Small
Beak rush	Rhynchospora glomerata (L.) Vahl

Appendix II-A. Continued.

Common name	Scientific name
Beaked cornsalad	*Valerianella radiata* (L.) Dufr.
Beard grass	*Bothriochloa saccharoides* var. *longipaniculata* (Gould) Gould
Beard-tongue	*Penstemon laxiflorus* Penn.
** Beard-tongue	*Penstemon tenuis* Small
Bear's foot	*Polymnia Uvedalia* (L.) L.
Beggar-ticks	*Bidens discoidea* (T. & G.) Britt.
Beggar-ticks	*Bidens laevis* (L.) B.S.P.
Beggar's-ticks	*Desmodium Nuttallii* (Schindl.) Schul.
Beggar's-ticks	*Desmodium obtusum* (Willd.) DC.
Beggar's-ticks	*Desmodium viridiflorum* (L.) DC.
Burmuda grass	*Cynodon Dactylon* (L.) Pers.
Big bluestem	*Andropogon Gerardi* Vitman
Bitterweed	*Helenium amarum* (Raf.) Rock
Black medic	*Medicago Lupulina* L.
Blackseed needlegrass	*Stipa avenacea* L.
Black snakeroot	*Sanicula canadensis* L.
Bladder-pod	*Lesquerella recurvata* (Gray) Wats.
Bladder pod	*Sesbania vesicaria* (Jacq.) Ell.
Bladder sedge	*Carex intumescens* Rudge
Bladderwort	*Utricularia subulata* L.
Blazing-star	*Liatris pycnostachya* Michx.
Blister buttercup	*Ranunculus sceleratus* L.

Appendix II-a. Continued.

Common name	Scientific name
Bloodleaf	*Iresine rhizomatosa* Standl.
Blue-eyed grass	*Sisyrinchium Langloisii* Greene
Blue-eyed grass	*Sisyrinchium pruinosum* Bickn.
Bluegrass	*Poa annua* L.
Bluegrass	*Poa autumnalis* Ell.
Blue jasmine	*Clematis crispa* L.
Blue larkspur	*Delphinium carolinianum* Walt.
* Blue sage	*Salvia azurea* Lam.
Blue star	*Amsonia illustris* Woods.
Bluet	*Hedyotis nigricans* (Lam.) Fosb.
Bluet	*Hedyotis uniflora* (L.) Lam.
Blunt-lobed woodsia	*Woodsia obtusa* (Spreng.) Torr.
Blunt spikerush	*Eleocharis obtusa* (Willd.) Schult.
Bog-hemp	*Boehmeria cylindrica* (L.) Sw. var. *cylindrica*
Bog marsh-cress	*Rorippa islandica* (Oeder) Borbas
Bog-rush	*Juncus trigonocarpus* Steud.
Branched sedge	*Carex decomposita* Muhl.
Brazilian vervain	*Verbena brasiliensis* Vell.
Britton sedge	*Carex Brittoniana* Bailey
Broadleaf signalgrass	*Brachiaria platyphylla* (Griseb.) Nash
Brome	*Bromus commutatus* Schrad.
Brookweed	*Samolus parviflorus* Raf.

Appendix II-a. Continued.

Common name	Scientific name
Broomsedge	Andropogon virginicus L.
Broomweed	Xanthocephalum dracunculoides (DC.) Shinners
Broomweed	Xanthocephalum texanum (DC.) Shinners
Brownseed paspalum	Paspalum plicatulum Michx.
Browntop panic grass	Panicum fasciculatum Sw.
Buckthorn	Plantago aristata Michx.
Buffalo bur	Solanum rostratum Dun.
Buffalo gourd	Cucurbita foetidissima H.B.K.
Buffalo grass	Buchloe dactyloides (Nutt.) Engelm.
Bull-nettle	Cnidoscolus texanus (Muell. Arg.) Small
Bull-thistle	Circium horridulum Michx.
Bulrush	Scirpus koilolepis (Steud.) Gl.
Bluntleaf bedstraw	Galium obtusum Bigel.
Bur-clover	Medicago polymorpha var. vulgaris (Benth.) Shinners
Burhead	Echinodorus cordifolius (L.) Griseb.
Burhead	Echinodorus rostratus (Nutt.) Engelm.
Butter-and-eggs	Linaria vulgaris Mill.
Buttercup	Ranunculus carolinianus DC.
Buttercup	Ranunculus pusillus Poir.
Butterfly pea	Centrosema virginianum (L.) Benth.
Butterfly weed	Asclepias tuberosa L.

Appendix II-a. Continued.

Common name	Scientific name
Butterweed	*Senecio glabellus* Poir.
Button clover	*Medicago orbicularis* (L.) Bartal.
Button weed	*Diodia virginiana* L.
Camphor-weed	*Pluchea camphorata* (L.) DC.
Canada wild-rye	*Elymus canadensis* L.
Canary grass	*Phalaris canariensis* L.
Canary grass	*Phalaris caroliniana* Walt.
Cardinal flower	*Lobelia cardinalis* L. var. *cardinalis*
Carolina clover	*Trifolium carolinianum* Michx.
Carolina geranium	*Geranium carolinianum* L.
Carolina horse-nettle	*Solanum carolinense* L.
Carolina modiola	*Modiola caroliniana* (L.) G.Don.
Carolina sedge	*Carex caroliniana* Schwein.
Carpet grass	*Axonopus affinis* Chase
Catchfly grass	*Leersia lenticularis* Michx.
Catchweed bedstraw	*Galium Aparine* L.
Cat-tail	*Typha domingensis* Pers.
Chain fern	*Lorinseria areolata* (L.) Presl.
Chasmanthium	*Chasmanthium laxum* (L.) Yates
Chervil	*Chaerophyllum Tainturieri* Hook. var *Tainturieri*
Chicken spike	*Sphenoclea zeylanica* Gaert.
Chickweed	*Cerastium brachypodum* (Engelm.) Robins.

Appendix II-a. Continued.

	Common name	Scientific name
	Chickweed	Cerastium glomeratum Thuill.
	Christmas fern	Polystichum acrostichoides (Michx.) Schott
**	Cinnamon fern	Osmunda cinnamomea L.
	Clammy groundcherry	Physalis heterophylla Nees
	Clammy-weed	Polanisia erosa (Nutt.) Iltis subsp. erosa
	Clasping Venus' looking glass	Triodanis perfoliata (L.) Nieuw.
	Climbing dogbane	Trachelospermum difforme Gray
**	Climbing fern	Lygodium palmatum (Bernh.) Sw.
	Climbing hemp-weed	Mikania scandens (L.) Willd.
	Coast sandbur	Cenchrus incertus M. A. Curtis
	Cocklebur	Xanthium strumarium L.
	Common cat-tail	Typha latifolia L.
	Common chickweed	Stellaria media (L.) Cyr.
	Common green-briar	Smilax rotundifolia L.
	Common horehound	Marrubium vulgare L.
	Common mouse ear	Cerastium vulgatum L.
	Common mullein	Verbascum Thapsus L.
	Common self-heal	Prunella vulgaris L.
	Common sunflower	Helianthus annuus L.
	Common yarrow	Achillea millefolium L.
	Cone-spur bladderwort	Utricularia gibba L.

Appendix II-a. Continued.

Common name	Scientific name
Coral bean	Erythrina herbacea L.
Coreopsis	Coreopsis cardaminaefolia (DC.) Nutt.
Cotton thistle	Onopordum Acanthium L.
Cowpen daisy	Verbesina enceloides (Cav.) Gray
Creeping bush clover	Lespedeza repens (L.) Bart.
Creeping rush	Juncus repens Michx.
Creeping spot flower	Spilanthes americana var. repens (Walt.) A.H. Moore.
Creeping water primrose	Ludwigia peploides (H.B.K.) Raven subsp. peploides
Croton	Croton glandulosus L.
Croton	Croton Lindheimerianus Muell.
Crowfoot sedge	Carex crus-corvi Kunze
Crow poison	Nothoscordum bivalve (L.) Britt.
Cudweed	Gnaphalium falcatum Lam.
Cudweed	Gnaphalium pensilvanicum Willd.
Cupgrass	Eriochloa sericea (Scheele) Monro.
Cut-leaved evening primrose	Oenothera laciniata Hill.
Cylindric-fruited ludwigia	Ludwigia glandulosa Walt.
Dakota vervain	Verbena bipinnatifida Nutt.
Dayflower	Commelina communis L.
Dayflower	Commelina erecta L.
Dayflower	Commelina erecta var. Deamiana Fern.
Deer pea vetch	Vicia ludoviciana Nutt.

Appendix II-a. Continued.

Common name	Scientific name
Deer vetch	Lotus Purshianus (Benth.) Clem. & Clem.
Dichanthium	Dichanthium annulatum Stapf
Dicliptera	Dicliptera brachiata (Pursh) Spreng.
Ditch stonecrop	Penthorum sedoides L.
Dock	Rumex chrysocarpus Moris
Dodder	Cuscuta compacta Juss.
Dognettle	Urtica urens L.
Downy chess	Bromus tectorum L.
Downy ground cherry	Physalis pubescens var. integrifolia (Dun.) Waterfall
Dracopis	Dracopis amplexicaulis (Vahl) Cass.
Drummond phlox	Phlox Drummondii Hook.
** Drummond wax-mallow	Malvaviscus arboreus var. Drummondii (T. & G.) Schery
Duck potato	Sagittaria latifolia Willd.
Dwarf dandelion	Krigia gracilis (DC.) Shinners
Dwarf dandelion	Krigia virginica (L.) Willd.
Dwarf spikerush	Eleocharis parvula (R. & S.) Link
Dye bedstraw	Galium tinctorium L.
Ebony spleenwort	Asplenium platyneuron (L.) D. C. Eat.
Echinochloa	Echinochloa Walteri (Pursh) Heller
Eclipta	Eclipta alba (L.) Hassk.
Elephant's-foot	Elephantopus carolinianus Raeusch.

Appendix II-a. Continued.

Common name	Scientific name
Elephant's-foot	Elephantopus tomentosus L.
Engelmann daisy	Engelmannia pinnatifida Nutt.
Eryngo	Eryngium Hookeri Walp.
Eryngo	Eryngium integrifolium Walt.
Evening primrose	Oenothera heterophylla Spach.
Eyebane	Euphorbia nutans Lag.
Fall panic	Panicum dichotomiflorum Michx.
Fall witchgrass	Leptoloma cognatum (Schult.) Chase
False dandelion	Pyrrhopappus carolinianus (Walt.) DC.
False dandelion	Pyrrhopappus multicaulis DC.
False pimpernel	Lindernia anagallidea (Michx.) Penn.
False ragweed	Parthenium Hysterophorus L.
Fewflower tickclover	Desmodium pauciflorum (Nutt.) DC.
Fiddle dock	Rumex pulcher L.
Fimbristylis	Fimbristylis autumnalis (L.) R. & S.
Finger dogshade	Cynosciadium digitatum DC.
** Finger lionsheart	Physostegia Digitalis Small
Fireweed	Erechtites hieracifolia var. intermedia Fern.
Flat sedge	Cyperus acuminatus T. & G.
Flat sedge	Cyperus brevifolius (Rottb.) Hassk.
Flat sedge	Cyperus erythrorhizos Muhl.
Flat sedge	Cyperus globulosus Aubl.

Appendix II-a. Continued.

Common name	Scientific name
Flat sedge	*Cyperus Haspan* L.
Flat sedge	*Cyperus odoratus* L.
Flat sedge	*Cyperus ovularis* (Michx.) Torr.
Flat sedge	*Cyperus pseudovegatus* Steud.
Flat sedge	*Cyperus polystachyos* var. *texensis* (Torr.) Fern.
Flat sedge	*Cyperus retrofractus* (L.) T. & G.
Flat sedge	*Cyperus setigerus* T. & H.
Flat sedge	*Cyperus strigosus* L.
Flat sedge	*Cyperus surinamensis* Rottb.
Fleabane	*Erigeron tenuis* T. & G.
Flower-of-an-hour	*Hibiscus trionum* L.
Forget-me-not	*Myosotis verna* Nutt.
Forked blue curls	*Trichostema dichotomum* L.
Forked rush	*Juncus dichotomus* Ell.
Fourspike heliotrope	*Heliotropium procumbens* Mill.
Fox sedge	*Carex vulpinoidea* Michx.
Foxtail	*Alopecurus carolinianus* Walt.
Fragile fern	*Cystopteris fragilis* (L.) Bernh.
Fragrant cudweed	*Gnaphalium obtusifolium* L.
Frostweed	*Verbesina virginica* L.
Franks sedge	*Carex Frankii* Kunth.
Fringed signalgrass	*Brachiaria ciliatissima* (Buckl.) Chase

Appendix II-a. Continued.

Common name	Scientific name
Gaura	Gaura filiformis Small
Gay feather	Liatris elegans (Walt.) Michx.
Giant ragweed	Ambrosia trifida L.
Globe-berry	Ibervillea Lindheimeri (Gray) Greene
Golden aster	Heterotheca latifolia Buckl.
Golden aster	Heterotheca pilosa (Nutt.) Shinners
Goldenrod	Solidago altissima L.
Goldenrod	Solidago nitida T. & G.
Goldenrod	Solidago nemoralis Ait.
Grassleaf rush	Juncus marginatus Rostk.
Gray vervain	Verbena canescens H.B.K.
Green amaranth	Amaranthus viridis L.
Green dragon	Arisaema Dracontium (L.) Schott.
Green-eyes	Berlandiera pumila (Michx.) Nutt.
Green gerardia	Agalinis viridis (Small) Penn.
Green parrot's feathers	Myriophyllum pinnatum (Walt.) B.S.P.
Green-thread	Thelesperma flavodiscum (Shinners) B. L. Turner
Gromwell	Lithospermum tuberosum A. DC.
Ground cherry	Physalis angulata L.
Ground cherry	Physalis angulata var. pendula (Rydb.) Waterfall
Ground cherry	Physalis virginiana Mill.

Appendix II-a. Continued.

Common name	Scientific name
Groundsel	*Senecio imparipinnatus* Klatt
Gulf croton	*Croton punctatus* Jacq.
Gulf vervain	*Verbena xutha* Lehm.
Gummy lovegrass	*Eragrostis curtipedicellata* Buckl.
Hairy four-o-clock	*Mirabilis hirsuta* (Pursh) MacM.
Hairyseed paspalum	*Paspalum pubiflorum* Fourn.
Hairy bush clover	*Lespedeza hirsuta* (L.) Hornem.
Hairy grama	*Bouteloua hirsuta* Lag.
Hairy vetch	*Vicia villosa* Kuth.
Hammerwort	*Parietaria pensylvanica* Muhl.
Hawk's-beard	*Crepis capillaris* (L.) Wallr.
Heartleaf nettle	*Urtica chamaedryoides* Pursh
Heartleaf nettle	*Urtica chamaedryoides* var. *Runyonii* Correll
Heart sorrel	*Rumex hastatulus* Ell.
Hedge-parsley	*Torilus arvensis* (Huds.) Link
Hoary tickclover	*Desmodium canescens* (L.) DC.
Hooked pepperwort	*Marsilea uncinata* A. Br.
Hooker eryngo	*Eryngium Hookeri* Walp.
Horned rush	*Rhynchospora corniculata* (Lan.) Gray
Horsemint	*Monarda citriodora* Cerv.
Horsetail	*Equisetum hyemale* var. *affine* (Engelm.) A.A. Eaton

Appendix II-a. Continued.

Common name	Scientific name
Horse-weed	*Conyza canadensis* (L.) Cronq.
Hummock sedge	*Carex Joori* Bailey
Hydrolea	*Hydrolea ovata* Choisy
Illinois bundleflower	*Desmanthus illinoiensis* (Michx.) MacM.
India heliotrope	*Heliotropium indicum* L.
Indian blanket	*Gaillardia pulchella* Foug.
Indian chickweed	*Mollugo verticillata* L.
Indian grass	*Sorghastrum avenaceum* (Michx.) Nash
Indian hemp	*Apocynum cannabinum* L.
Indian strawberry	*Duchesnea indica* (Andrz.) Focke
Inland sea oats	*Chasmanthium latifolium* (Michx.) Yates
Inland rush	*Juncus interior* Wieg.
Intermediate lions heart	*Physostegia intermedia* (Nutt.) Engelm. & Gray
Ironweed	*Vernonia missurica* Raf.
Ironweed	*Vernonia texana* (Gray) Small
Ivy treebine	*Cissus incisa* (Nutt.) Des Moul.
Japanese bushclover	*Lespedeza striata* (Thumb.) H. & A.
Japanese chess	*Bromus japonicus* L.
Johnson grass	*Sorghum halepense* (L.) Pers.
Joint-tail	*Manisuria rugosa* (Nutt.) O. Ktze.
Jumpseed	*Polygonum virginianum* L.
Jungle-rice	*Echinochloa colonum* (L.) Link

Appendix II-a. Continued.

Common name	Scientific name
Juniper leaf	*Polypremum procumbens* L.
Kallstroemia	*Kallstroemia parviflora* Mort.
Knotted hedge-parsley	*Torilis nodosa* (L.) Gaert.
Knotweed	*Polygonum cristatum* Engelm.
Lance-leaved water-willow	*Justicia lanceolata* (Chapm.) Small
Late-flowering thoroughwort	*Eupatorium serotinum* Michx.
Leaf-flower	*Phyllanthus polygonoides* Spreng.
Leaf-flower	*Phyllanthus pudens* Wheeler
Leather-flower	*Clematis Pitcheri* T. & G.
Leathery rush	*Juncus coriaceus* Mack.
Leavenworth vetch	*Vicia Leavenworthii* T. & G.
Leucospora	*Leucospora multifida* (Michx.) Nutt.
Leersia	*Leersia hexandra* Sw.
Lettuce	*Lactuca floridana* (L.) Gaertn.
Little barley	*Hordeum pusillum* Nutt.
Little bluestem	*Schizachyrium scoparium* (Michx.) Nash
Little burclover	*Medicago minima* (L.) L.
Little mallow	*Malva parviflora* L.
Little quaking grass	*Briza minor* L.
** Lizard's tail	*Saururus cernuus* L.
Lovegrass	*Eragrostis hirsuta* (Michx.) Nees
Lovegrass	*Eragrostis hypnoides* (Lam.) B.S.P.

ıppendix II-a. Continued.

Common name	Scientific name
Low hopclover	_Trifolium campestre_ Sturm.
Low poppy-mallow	_Callirhoe involucrata_ (Torr.) Gray
Lyre-leaf sage	_Salvia lyrata_ L.
Maidencane	_Panicum hemitomon_ Schult.
Marigold dogwood	_Dyssodia tagetoides_ T. & G.
Marijuana	_Cannabis sativa_ L.
Marsh-elder	_Iva angustifolia_ DC.
Marsh-elder	_Iva annua_ L.
Marsh-fleabane	_Pluchea purpurascens_ (Sw.) DC.
Marsh purslane	_Ludwigia palustris_ (L.) Ell.
Maryland senna	_Cassia marilandica_ L.
Mauchia	_Bradburia hirtella_ T. & G.
Maximilian sunflower	_Helianthus Maximiliani_ Schrad.
Meadow beauty	_Rhexia mariana_ L.
Meadow beauty	_Rhexia petiolata_ Walt.
Melonette	_Melothria pendula_ L.
Mexican hat	_Ratibida columnaris_ (Sims) D. Don.
Milkweed	_Asclepias obovata_ Ell.
Milkweed	_Asclepias rubra_ L.
Milkweed	_Asclepias viridiflora_ Raf.
Missouri violet	_Viola missouriensis_ Greene
Mist-flower	_Eupatorium coelestinum_ L.

Appendix II-a. Continued.

Common name	Scientific name
Mock bishop's-weed	Ptilimnium capillaceum (Michx.) Raf.
Mock pennyroyal	Hedeoma Drummondii Benth.
Mock pennyroyal	Hedeoma hispidum Pursh
Monkey-flower	Mimulus alatus Ait.
Morning glory	Ipomea lacunosa L.
Morning glory	Ipomea trichocarpa Ell.
Muhlenburg sedge	Carex Muhlenbergii Schkuhr.
Muhly	Muhlenbergia brachyphylla Bush
Nama	Nama hispidum Gray
Narrow cell cornsalad	Valerianella stenocarpa (Engelm.) Krok
Narrow-leaved vetch	Vicia angustifolia L.
Narrow plumegrass	Erianthus strictus Baldw.
Nimblewill muhly	Muhlenbergia Schreberi J. F. Gmel.
Northern crabgrass	Digitaria sanguinalis (L.) Scop.
Northern frog fruit	Phyla lanceolata (Michx.) Greene
Noseburn	Tragia cordata Michx.
Noseburn	Tragia ramosa Torr.
Nutgrass	Cyperus rotundus L.
Oats	Avena fatua L.
Old field toad-flax	Linaria canadensis (L.) Dum.
Old plainsman	Hymenopappus Scabiosaeus L. Her.

Appendix II-a. Continued.

Common name	Scientific name
Oplismenus	Oplismenus hirtellus subsp. setarius (Lam.) Mez
Ox-eye	Heliopsis helianthoides (L.) Sweet
Ozark grass	Limnodea arkansana (Nutt.) L. H. Dewey
Palafoxia	Palafoxia Reverchonii (Bush) Cory
Palafoxia	Palafoxia rosea (Bush) Cory
Pale dock	Rumex altissimus Wood
Pale-seeded plantain	Plantago virginica L.
Panic grass	Panicum anceps Michx.
Panic grass	Panicum brachyanthum Steud.
Panic grass	Panicum dichotomum L.
Panic grass	Panicum dilatatum Poir.
Panic grass	Panicum geminatum Michx.
Panic grass	Panicum hians Ell.
Panic grass	Panicum oligosanthes Schult.
Panic grass	Panicum rigidulum Nees
Panic grass	Panicum verrucosum Muhl.
Panicled tickclover	Desmodium paniculatum (L.) DC.
Partridge pea	Cassia fasciculata Michx.
Partridge pea	Cassia fasciculata var. rostrata (Woot. & Standl.) B. L. Turner
Paspalum	Paspalum acuminatum Raddi
Paspalum	Paspalum floridanum Michx.

Appendix II-a. Continued

Common name	Scientific name
Paspalum	*Paspalum fluitans* (Ell.) Kunth
Paspalum	*Paspalum laeve* Michx.
Paspalum	*Paspalum Lange* (Fourn.) Nash
Paspalum	*Paspalum praecox* Walt.
Peanut clover	*Trifolium amphianthum* T. & G.
Pencil-flower	*Stylosanthes biflora* (L.) B. S. P.
Peppergrass	*Lepidium virginicum* L.
Peppervine	*Ampelopsis arborea* (L.) Koehne
Persian clover	*Trifolium resupinatum* L.
Persicaria	*Persicaria densiflora* (Meisn.) Moldenke
Phacelia	*Phacelia hirsuta* Nutt.
Phlox	*Phlox pilosa* L.
Pickerel-weed	*Pontederia cordata* L.
Pink smartweed	*Persicaria bicornis* (Raf.) Nieuw.
Pipewort	*Eriocaulon decangulare* L.
Pitseed goosefoot	*Chenopodium Berlandieri* Moq.
Plains wild indigo	*Baptisia leucophaea* Nutt.
Poke weed	*Phytolacca americana* L.
Polygala	*Polygala cruciata* L.
Polygala	*Polygala ramosa* Ell.
Pony-foot	*Dichondra carolinensis* Michx.
Power puff	*Mimosa strigillosa* T. & G.

Appendix II-a. Continued

Common name	Scientific name
Prairie Agalinis	*Agalinis heterophylla* (Nutt.) Small
Prairie clover	*Petalostemum candidum* (Willd.) Michx.
Prairie cupgrass	*Eriochloa contracta* Hitchc.
Prairie ground cherry	*Physalis pumila* Nutt.
Prairie-parsley	*Polytaenia Nuttallii* DC.
Prairie tea	*Croton monanthogynus* Michx.
Prairie three-awn	*Aristida oligantha* Michx.
Prairie wedgescale	*Sphenopholis obtusata* (Michx.) Scribn.
Prickly lettuce	*Lactuca serriola* L.
Prickly mallow	*Sida spinosa* L.
Prickly poppy	*Argemone polyanthemos* (Fedde) G. Ownbey
Primrose-willow	*Ludwigia decurrens* Walt.
Prionopsis	*Prionopsis ciliata* (Nutt.) Nutt.
Prostrate lawnflower	*Calyptocarpus vialis* Less.
Puncture vine	*Tribulus terrestris* L.
Purple amaranth	*Amaranthus cruentus* L.
Purple cudweed	*Gnaphalium purpureum* L.
Purple meadow-rue	*Thalictrum Dasycarpum* Fisch. & All.
Purple sandgrass	*Triplasis purpurea* (Walt.) Chapm.
Purple three-awn	*Aristida purpurea* Nutt.
Purpletop	*Tridens flavus* (L.) Hitchc.
Purslane speedwell	*Veronica peregrina* L.

Appendix II-a. Continued

Common name	Scientific name
Rain-lily	Cooperia Drummondii Herb.
Rattle-box	Ludwigia alternifolia L.
Rattlesnake-weed	Daucus pusillus Michx.
Red Lovegrass	Eragrostis oxylepis (Torr.) Torr.
Red-seeded plantain	Plantago rhodosperma Dcne.
Red sprangle top	Leptochloa Filiformis (Lam.) Beauv.
Redtop bentgrass	Agrostis stolonifera L.
Reflexed sedge	Carex retroflexa Michx.
Rescue grass	Bromus unioloides H.B.K.
** Rice cutgrass	Leersia oryzoides (L.) Sw.
Rose gentian	Sabatia campestris Nutt.
Rose vervain	Verbena canadensis (L.) Britt.
Rough buttonweed	Diodia teres Walt.
Roundhead rush	Juncus validus Cov.
Roundleaf scurfpea	Psoralea rhombifolia T. & G.
** Royal fern	Osmunda regalis var. spectabilis (Willd.) Gray
Ruellia	Ruellia caroliniensis (Walt.) Steud.
Ruellia	Ruellia humilis var. longiflora (Gray) Fern.
Rush	Juncus nodatus Cov.
Rush-foil	Crotonopsis linearis Michx.
Ryegrass	Lolium perenne L.

Appendix II-a. Continued

Common name	Scientific name
Sacciolepis	Sacciolepis striata (L.) Nash
Salsify	Tragopogon porrifolius L.
Sandhills amaranth	Amaranthus arenicola I. M. Johnst.
Sand spikerush	Eleocharis montevidensis Kunth.
Sandwort	Arenaria patula Michx.
Scaleseed	Spermolepis inermis (DC.) Math. & Const.
Scarlet pea	Indigofera miniata Ort.
Scarlet pimpernel	Anagallis arvensis L.
Scarlet rose-mallow	Hibiscus militaris Cav.
Scarlet spiderling	Boerhaavia coccinea Mill.
Scorpion grass	Myosotis macrosperma Engelm.
Scrambled eggs	Corydalis aurea Willd.
Scratch-daisy	Croptilon divaricatum (Nutt.) Raf.
Sedge	Carex albolutescens Schwein.
Sedge	Carex amphibola Steud.
Sedge	Carex blanda Dew.
Sedge	Carex crebriflora Wieg.
Sedge	Carex cherokeensis Schwein.
Sedge	Carex Davisii Schwein. & Torr.
Sedge	Carex lurida Wahl.
Sedge	Carex reniformis (Bailey) Small

Appendix II-a. Continued

Common name	Scientific name
Sensitive Fern	Onoclea sensibilis L.
Sesbania	Sesbania macrocarpa Muhl.
Sessile-leaf Tickclover	Desmodium sessilifolium (Torr.) T. & G.
Setaria	Setaria geniculata (Lam.) Beauv.
Shade betony	Stachys crenata Raf.
Shade mud-flower	Micranthemum umbrosum (Walt.) Blake
Shepherd's purse	Capsella Bursa-Pastoris (L.) Medic.
Shore milkweed	Asclepias perennis Walt.
Short ragweed	Ambr[illegible] [illegible]lifol[illegible]
Shortstem Iris	Iris [illegible] Raf.
Showy Primrose	Oenothera speciosa Nutt.
Sicklepod	Cassia obtusifolia L.
Sida	Sida rhombifolia L.
Side-oats grama	Bouteloua curtipendula (Michx.) Torr.
Silver bluestem	Bothriochloa Saccharoides (Sw.) Rydb.
Silverleaf nightshade	Solanum elaeagnifolium Cav.
Singletary pea	Lathyrus hirsutus L.
Six-weeks fescue	Vulpia octoflora (Walt.) Rydb.
Skullcap	Scutellaria cardiophylla Engelm. & Gray
Slender rush	Juncus tenuis Willd.
Slick-seed bean	Strophostyles leiosperma (T. & G.) Piper

Appendix II-a. Continued

Common name	Scientific name
Slimleaf scurfpea	_Psoralea tenuiflora_ Pursh
Slimlobe celery	_Apium leptophyllum_ (Pers.) F. V. Muell.
Slimlobe poppy-mallow	_Callirhoe involucrata_ var. _lineariloba_ (T. & G.) Gray
Slimpod rush	_Juncus difussimus_ Buckl.
Small-flowered vervain	_Verbena bipinnatifida_ Nutt.
Small Venus' looking glass	_Triodanis biflora_ (R. & P.) Greene
Smartweed	_Persicaria coccinea_ (Muhl.) Green
Smartweed	_Persicaria hydropiperoides_ (Michx.) Small
Smartweed	_Persicaria lapathifolia_ (L.) Small
Smartweed	_Persicaria punctata_ (Ell.) Small
Smooth buttonweed	_Spermacoce glabra_ Michx.
Smooth hydrolea	_Hydrolea uniflora_ Raf.
Smutgrass	_Sporobolus indicus_ (L.) R. Br.
Snake-cotton	_Froelichia Braunii_ Standl.
Snake-cotton	_Froelichia Drummondii_ Moq.
Snake-cotton	_Froelichia floridana_ (Nutt.) Moq.
Sneezeweed	_Helenium autumnale_ L.
Sneezeweed	_Helenium microcephalum_ DC.
Sneezeweed	_Helenium quadridentatum_ Labill.
Snow-on-the-prairie	_Euphorbia bicolor_ Engelm. & Gray
Snoutbean	_Rhynchosia latifolia_ (Nutt.) T. & G.

Appendix II-a. Continued

	Common name	Scientific name
	Soft rush	*Juncus effusus* var. *solutus* Fern. & Wieg.
	Sorghum	*Sorghum bicolor* (L.) Moench.
	Sourclover	*Melilotus indicus* (L.) All.
**	Southern blue-flag	*Iris virginica* L.
	Southern crabgrass	*Digitaria adscendens* (H. B. K.) Henr.
	Southern wildrice	*Zizaniopsis miliacea* (Michx.) Doell. & Asch.
	Southernshield fern	*Thelypteris Kunthii* (Desv.) Morton
	Sow thistle	*Sonchus asper* (L.) Hill
	Sow thistle	*Sonchus oleraceus* L.
	Spanish moss	*Tillandsia usneoides* (L.) L.
	Spanish-needles	*Bidens bipinnata* L.
	Spiderwort	*Commelina virginica* L.
	Spiderwort	*Tradescantia hirsutiflora* Bush
	Spiderwort	*Tradescantia ohioensis* Raf.
	Spiderwort	*Tradescantia Reverchonii* Bush
	Spikerush	*Eleocharis austrotexana* M. C. Johnst.
	Spikerush	*Eleocharis macrostachya* Britt.
	Spikerush	*Eleocharis tortilis* (Link.) Schult.
	Spiny pigweed	*Amaranthus spinosus* L.
	Splitbeard bluestem	*Andropogon ternarius* Michx.

Appendix II-a. Continued

	Common name	Scientific name
	Spotted beebalm	Monarda punctata L.
	Spotted bur-clover	Medicago arabica (L.) Huds.
	Spreading dayflower	Commelina diffusa Burm. F.
	Spring bentgrass	Agrostis hyemalis (Walt.) B. S. P.
**	Spring ladies' tresses	Spiranthes vernalis Engelm. & Gray
	Spurge	Euphorbia dentata Michx.
	Spurge	Euphorbia maculata L.
	Spurge	Euphorbia missurica Raf.
	Spurge	Euphorbia prostrata Ait.
	Spurge	Euphorbia serpens H. B. K.
	Spurge	Euphorbia spathulata Lam.
	Squarestem spikerush	Eleocharis quadrangulata (Michx.) R. & S.
	Sticky hedge-hyssop	Gratiola brevifolia Raf.
	Stinking-fleabane	Pluchea foetida (L.) DC.
	St. John's-wort	Hypericum mutilum L.
	St. John's-wort	Hpericum Walteri Gmel.
	Sugarcane plumegrass	Erianthus giganteus (Walt.) Muhl.
	Sunflower	Helianthus angustifolius L.
	Sunflower	Helianthus debilis Nutt.
	Sunflower	Helianthus grosse-serratus Martens
	Swampdock	Rumex verticillatus L.
	Sweet goldenrod	Solidago odora Ait.

Appendix II-a. Continued

Common name	Scientific name
Tall bush clover	Lespedeza Stuevei Nutt.
Tall dropseed	Sporobolus asper (Michx.) Kunth
Tallow weed	Plantago Hookeriana Fisch. & Mey.
Texas aster	Aster texanus Burgess
Texas bedstraw	Galium texense Gray
Texas bluebonnet	Lupinus texensis Hook.
Texas frog-fruit	Phyla incisa Small
Texas geranium	Geranium texanum (Trel.) Heller
Texas gourd	Cucurbita texana Gray
Texas grama	Bouteloua rigidiseta (Steud.) Hitchc.
Texas groundsel	Senecio ampullaceus Hook.
Texas millet	Panicum texanum Buckl.
Texas paintbrush	Castilleja indivisa Engelm.
Texas pink-root	Spigelia texana (T. & G.) A. DC.
Texas speargrass	Stipa leucotricha Trin. & Rupr.
Texas thistle	Cirsium texanum Buckl.
Texas toad-flax	Linaria texana Scheele
Texas vervain	Verbena Halei Small
Texas yellow-star	Lindheimera texana Gray & Engelm.
Thin paspalum	Paspalum setaceum Michx.
Thoroughwort	Eupatorium perfoliatum L.
Thoroughwort	Eupatorium rotundifolium L.

Appendix II-a. Continued

Common name	Scientific name
Three-awn grass	_Aristida desmantha_ Trin. & Rupr.
Three-awn grass	_Aristida lanosa_ Ell.
Three-awn grass	_Aristida longespica_ Poir.
Three-seeded Mercury	_Acalypha gracilens_ Gray
Three-seeded Mercury	_Acalypha ostryaefolia_ Ridd.
Three-seeded Mercury	_Acalypha rhomboidea_ Raf.
Three-seeded Mercury	_Acalypha virginica_ L.
Tick-seed	_Coreopsis basalis_ (Otto. & Dietr.) Blake
Tick-seed	_Coreopsis nuecensis_ Heller
Tick-seed	_Coreopsis tinctoria_ Nutt.
Toad-rush	_Juncus bufonius_ L.
Toothcup	_Ammannia coccinea_ Rottb.
Toothcup	_Rotala ramosior_ (L.) Koehne
Tomato	_Lycopersicon esculentum_ Mill.
Trailing ratany	_Krameria lanceolata_ Torr.
Tridens	_Tridens strictus_ (Nutt.) Nash.
Tropical crabgrass	_Digitaria diversiflora_ Swall.
Tuckahoe	_Peltandra virginica_ (L.) Kunth
Tumblegrass	_Schedonnardus paniculatus_ Nutt.
Turnsole	_Heliotropium tenellum_ (Nutt.) Torr.
Two-eyed berry	_Mitchella repens_ L.

Appendix II-a. Continued

Common name	Scientific name
Two-flower melic	*Melica mutica* Walt.
Umbrella-grass	*Fuirena simplex* Vahl
Umbrella-grass	*Fuirena squarrosa* Michx.
Uruguay water primrose	*Ludwigia uruguayensis* (Camb.) Hara
Vahl fimbry	*Fimbristylis Vahlii* (Lam.) Link
Vasey grass	*Paspalum Urvillei* Steud.
Velvet-leaf gaura	*Gaura parviflora* Hook.
Venus' looking glass	*Triodanis texana* McVaugh
Vetch	*Vicia leavenworthii* T. & G.
Vine mesquite	*Panicum obtusum* H.B.K.
Violet wood-sorrel	*Oxalis violacea* L.
Virginia bugle-weed	*Lycopus virginicus* L.
Virginia wild rye	*Elymus virginicus* L.
Water clover	*Marsilea mucronata* A. Br.
Water-feather	*Myriophyllum brasiliense* Camb.
Water-horehound	*Lycopus rubellus* Moench.
Water-hyssop	*Bacopa Monnieri* (L.) Wettst.
Water-milfoil	*Myriophyllum verticillatum* L.
Water-pennywort	*Hydrocotyle umbellata* L.
Water-pennywort	*Hydrocotyle verticillata* Thunb.
Water-primrose	*Ludwigia leptocarpa* (Nutt.) Hara
Wedgegrass	*Sphenopholis filiformis* (Chapm.) Hitchc.

Appendix II-a. Continued

Common name	Scientific name
Wedgegrass	*Sphenopholis intermedia* (Rydb.) Rydb.
Wedgegrass	*Sphenopholis longiflora* (Vasey) Hitchc.
Weedy dandelion	*Krigia oppositifolia* Raf.
Weeping lovegrass	*Eragrostis curvula* (Schrad.) Nees
Western horse-nettle	*Solanum dimidiatum* Raf.
Western ragweed	*Ambrosia psilostachya* DC.
White avens	*Geum canadense* Jacq.
White clover	*Trifolium repens* L.
White grass	*Leersia virginica* Willd.
White root rush	*Juncus brachycarpus* Engelm.
White sheath sedge	*Carex hyaline* Boott
White sweet clover	*Melilotus albus* Lam.
White top daisy	*Erigeron strigosus* Willd.
White tridens	*Tridens albescens* (Vasey) Woot. & Stand.)
White vervain	*Verbena urticifolia* L.
Wild buckwheat	*Eriogonum longifolium* Nutt.
Wild buckwheat	*Eriogonum multiflorum* Benth.
Wild four o'clock	*Mirabilis nyctaginea* (Michx.) MacM.
Wild indigo	*Baptisia Nuttalliana* Small
Wild onion	*Allium canadense* L.
Wild petunia	*Ruellia Corzoi* Tharp & Barkl.

Appendix II-a. Continued

Common name	Scientific name
Wild petunia	*Ruellia pedunculata* Torr.
Wild petunia	*Ruellia strepens* L. var. *strepens*
Wild potato	*Ipomoea pandurata* (L.) Mey.
Windmill fingergrass	*Chloris verticillata* Nutt.
Wingseed	*Carex alata* Torr.
Witchgrass	*Panicum capillare* L.
Winter vetch	*Vicia dasycarpa* Ten.
Woods cornsalad	*Valerianella Woodsiana* (T. & G.) Walp.
Wood-sorrel	*Oxalis* [illegible] Jacq.
Woolly croton	*Croton capitatus* Michx.
Woolly rose-mallow	*Hibiscus lasiocarpus* Cav.
Woolly white	*Hymenopappus artemisiaefolius* DC.
Wormseed	*Chenopodium ambrosioides* L.
Yellow cow-lily	*Nuphar luteum* subsp. *macrophyllum* (Small) E. O. Beal
Yellow Cress	*Rorippa sessiliflora* (Nutt.) Hitchc.
Yellow Dock	*Rumex crispus* L.
Yellow-eyed grass	*Xyris iridifolia* Chapm.
Yellow-eyed grass	*Xyris Jupicai* Rich.
Yellow Nut grass	*Cyperus esculentus* L.
Yellow-purr	*Neptunia lutea* (LeavenW.) Benth.
Yellow-spine Thistle	*Cirsium ochrocentrum* Gray

Appendix II-a. Continued

Common name	Scientific name
Yellow Sweet Clover	<u>Melilotus officinalis</u> (L.) Lam.

Appendix II-b. Partial checklist of shrub, tree, and woody vine species within the Trinity River Basin including annotation of rare and endangered species according to the Rare Plant Study Center (1973) (indicated by *) and the Texas Organization for Endangered Species (1973) (indicated by **).

Common name	Scientific name
American basswood	*Tilia americana* L.
American beautyberry	*Callicarpa americana* L.
American elder	*Sambucus* [illegible] L.
American elm	*Ulmus americana* L.
American holly	*Ilex opaca* Ait.
American hop-hornbeam	*Ostrya virginiana* (Mill.) K. Koch
American starjasmine	*Trachelospermum difforme* (Walt.) Gray
Amorpha	*Amorpha paniculata* T. & G.
Bald cypress	*Taxodium distichum* (L.) Rich.
Bastard indigo	*Amorpha fruticosa* L.
Bastard oak	*Quercus sinuata* Walt.
Beech	*Fagus grandifolia* Ehrh.
Bitter orange	*Citrus trifoliata* L.
Bitternut hickory	*Carya cordiformis* (Wang.) K. Koch
Black cherry	*Prunus serotina* Ehrh.
Black gum	*Nyssa sylvatica* March.
Black hickory	*Carya texana* Buckl.
Black locust	*Robinia pseudo-acacia* L.

Appendix II-b. Continued.

Common name	Scientific name
** Black oak	Quercus velutina Lam.
Black walnut	Juglans nigra L.
Black willow	Salix nigra Marsh.
Blackjack oak	Quercus marilandica Muenchh.
Blue beech	Carpinus caroliniana L.
Bottomland post oak	Quercus similis Ashe
Box elder	Acer Negundo L.
Brazos hawthorne	Crataegus brazoria Sarg.
Bristly green-brier	Smilax hispida Muhl.
Buckthorn	Rhamnus lanceolata Pursh
Buffalo-gourd	Cucurbita foetidissima H. B. K.
** Bur oak	Quercus macrocarpa Michx.
Burning bush	Euonymus atropurpureus Jacq.
Bush palmetto	Sabal minor (Jacq.) Pers.
Carolina ash	Fraxinus caroliniana Mill.
Carolina basswood	Tilia caroliniana Mill.
Catalpa	Catalpa speciosa Warder
Cat-brier	Smilax bona-nox L.
Cedar elm	Ulmus crassifolia Nutt.
Chaste lamb-tree	Vitex agnus-castus L.
Chestnut oak	Quercus Prinus L.
Chickasaw plum	Prunus angustifolia Marsh.

Appendix II-b. Continued.

Common name	Scientific name
Chinaberry	*Melia azedarach* L.
Chinese tallow tree	*Sapium sebiferum* (L.) Roxb.
Cockspur hawthorn	*Crataegus crus-galli* L.
Common buttonbush	*Cephalanthus occidentalis* L.
Common green-brier	*Smilax rotundifolia* L.
Coral-berry	*Symphoricarpos orbiculatus* Moench.
Cow-itch	*Cissus incisa* (Nutt.) Des Moul.
Deciduous holly	*Ilex decidua* Walt.
Dewberry-blackberry	*Rubus aboriginum* Rydb.
Dewberry-blackberry	*Rubus apogaeus* Bailey
Dewberry-blackberry	*Rubus saepescandens* Bailey
Devil's-walking-stick	*Aralia spinosa* L.
Dogwood	*Cornus racemosa* Lam.
Downy hawthorn	*Crataegus mollis* Scheele
Drooping melonette	*Melothria pendula* L.
Drummond wax-mallow	*Malvaviscus arboreus* var. *Drummondii* (T. & G.) Schery
Eardrop vine	*Brunnichia ovata* (Walt.) Shinners
Eastern cottonwood	*Populus deltoides* Marsh.
Eastern red cedar	*Juniperus virginiana* L.
Eve's necklace	*Sophora affinis* T. & G.
Farkleberry	*Vaccinium arboreum* Marsh.
Florida basswood	*Tilia floridana* Small

Appendix II-b. Continued.

Common name	Scientific name
Flowering dogwood	Cornus florida L.
Forestiera	Forestiera ligustrina (Michx.) Poir.
Fragrant sumac	Rhus aromatica Ait.
Fringe-tree	Chionanthus virginica L.
Frost grape	Vitis riparia Michx.
Giant cane	Arundinaria gigantea (Walt.) Muhl.
Green ash	Fraxinus pensylvanica Marsh.
Green hawthorn	Crataegus viridis L.
Gum bumelia	Bumelia languinosa (Michx.) Pers.
Hawthorn	Crataegus glabriuscula Sarg.
Heartleaf	Ampelopsis cordata Michx.
Hersules-club	Zanthoxylum clava-herculis L.
Honey locust	Gleditsia triacanthos L.
Honey mesquite	Prosopis glandulosa Torr.
Indian cherry	Rhamnus caroliniana Walt.
Japanese honeysuckle	Lonicera japonica Thunb.
Laurel oak	Quercus laurifolia Michx.
Loblolly pine	Pinus taeda L.
Maypop passionflower	Passiflora incarnata L.
Mexican plum	Prunus mexicana Wats.
Milkvine	Matelea gonocarpa (Walt.) Shinners
Mistletoe	Phoradendron tomentosum (DC.) Gray

Appendix II-b. Continued.

	Common name	Scientific name
	Mockernut hickory	<u>Carya tomentosa</u> Nutt.
	Mock-orange	<u>Styrax americana</u> Lam.
	Muscadine grape	<u>Vitis rotundifolia</u> Michx.
	Mustang grape	<u>Vitis mustangensis</u> Buckl.
	Netleaf hackberry	<u>Celtis reticulata</u> Torr.
	O'possum-wood	<u>Halesia carolina</u> L.
	Osage orange	<u>Maclura pomifera</u> (Raf.) Schneid.
	Overcup oak	<u>Quercus lyrata</u> Walt.
	Parsley hawthorn	<u>Crataegus Marshallii</u> Eggl.
	Pasture haw	<u>Crataegus spathulata</u> Michx.
**	Pawpaw	<u>Asimina triloba</u> (L.) Dun.
	Peach	<u>Prunus persica</u> (L.) Batsch
	Pecan	<u>Carya illinoinensis</u> (Wang.) K. Koch
	Pepper vine	<u>Ampelopsis arborea</u> (L.) Koehne
	Persimmon	<u>Diospyros virginiana</u> L.
	Pigeon-berry	<u>Rivina humilis</u> L.
	Poison ivy	<u>Rhus toxicodendron</u> L.
	Possum-haw	<u>Viburnum nudum</u> L.
	Post oak	<u>Quercus stellata</u> Wang.
	Post oak grape	<u>Vitis lincecumii</u> Buckl.
	Prairie rose	<u>Rosa setigera</u> Michx.
	Privet	<u>Ligustrum</u> spp.

Appendix II-b. Continued.

Common name	Scientific name
Rattan vine	Berchemia scandens (Hill) K. Koch
Rattlebush	Sesbania Drummondii (Rydb.) Cory
Red bay	Persea borbonia (L.) Spreng.
Red grape	Vitis palmata Vahl
Red maple	Acer rubrum L.
Red mulberry	Morus rubra L.
Red-berried moonseed	Cocculus carolinus (L.) DC.
Redbud	Cercis canadensis L.
Redroot	Ceanothus herbaceus Raf.
Retama	Parkinsonia aculeata L.
River birch	Betula nigra L.
Roosevelt weed	Baccharis neglecta Britt.
** Roughleaf dogwood	Cornus Drummondii C. A. Mey.
Saltcedar	Tamarix gallica L.
Sandjack oak	Quercus incana Vartr.
Sassafras	Sassafras albidum (Nutt.) Nees
Sea-myrtle	Baccharis halimifolia L.
Shagbark hickory	Carya ovata (Mill.) K. Koch
Shining sumac	Rhus copallina L.
Shortleaf pine	Pinus echinata Mill.
Shumard red oak	Quercus Shumardii Buckl.
Skunk-bush	Ptelea trifoliata L.

Appendix II-b. Continued.

Common name	Scientific name
Slippery elm	Ulmus rubra Muhl.
Smooth alder	Alnus serrulata (Ait.) Willd.
Smooth sumac	Rhus glabra L.
Snowdrop-tree	Halesia diptera Ellis
Soap berry	Sapindus Saponaria L.
Southern arrow-wood	Viburnum dentatum L.
Southern blackhaw	Viburnum rufidulum Raf.
Southern dewberry	Rubus trivialis Michx.
Southern magnolia	Magnolia grandiflora L.
Southern red oak	Quercus falcata Michx.
St. Andrew's Cross	Ascyrum hypericoides L.
St. Peter's-wort	Ascyrum stans Michx.
Strawberry-bush	Euonymus americanus L.
Sugar maple	Acer saccharum Marsh.
Summer grape	Vitis aestivalis Michx.
Swamp privet	Forestiera acuminata (Michx.) Poir.
Sweet grape	Vitis cinerea Engelm.
Sweetgum	Liquidambar Styraciflua L.
Sweet-leaf	Symplocus tinctoria (L.) L'Her.
Sycamore	Platanus occidentalis L.
Tassel-white	Itea virginica L.
Texas nightshade	Solanum triquetrum Cav.

Appendix II-b. Continued.

Common name	Scientific name
Texas red oak	*Quercus texana* Buckl.
Texas sugarberry	*Celtis laevigata* Willd.
Trumpet honeysuckle	*Campsis radicans* (L.) Seem.
Tupelo	*Nyssa aquatica* L.
Virginia creeper	*Parthenocissus quinquefolia* (L.) Planch.
Water elm	*Planera aquatica* (Walt.) J. F. Gmel.
Water hickory	*Carya aquatica* (Michx. f.) Nutt.
Water locust	*Gleditsia aquatica* Marsh.
Water oak	*Quercus nigra* L.
Wax-leaf ligustrum	*Ligustrum Quihoui* Carr.
Wax myrtle	*Myrica cerifera* L.
White ash	*Fraxinus americana* L.
White mulberry	*Morus alba* L.
White oak	*Quercus alba* Michx.
Willow oak	*Quercus Phellos* L.
Winged elm	*Ulmus alata* Michx.
Winter grape	*Vitis vulpina* L.
Woolly dutchman's pipe	*Aristolochia tomentosa* Sims
Yaupon	*Ilex vomitoria* Ait.
Yellow passionflower	*Passiflora lutea* L.

CHAPTER III

LIMNOLOGIC-AQUATIC ELEMENTS

by

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INTRODUCTION

The purpose of this investigation has been to conduct environmental studies of the Trinity River Basin, expanding and quantifying certain baseline information revealed by previous literature and field surveys. Ten permanent general study areas (transects) were established along the Trinity River between Fort Worth and Wallisville Reservoir and are described elsewhere in this report. The specific objectives of this phase of the study included:

1. An investigation of water quality conditions at the 10 study sites.

2. An investigation of the phytoplankton productivity and diversity; the periphyton community composition and diversity.

3. An investigation of the total and fecal coliform, and fecal streptococcus bacteria counts and ratios.

4. Studies of the benthic macroinvertebrates including species composition, seasonal fluctuations and species diversity.

5. An investigation of the zooplankton community composition and diversity.

6. An investigation of the pesticide concentrations in the sediments and ground water.

7. An investigation of the particulate, dissolved and total organic carbon cencentrations in the Trinity River.

GENERAL METHODS AND PROCEDURES

Physical and Chemical Methods

Surface oxygen in parts per million, and temperature in degrees centigrade were measured in the field using a Yellow Springs Model 54 oxygen and temperature meter.

Transparency was determined in the field using the Secchi Disc method reported in Welch (1948), and is reported in feet.

Surface water samples were collected in disposable polyethylene containers, and were brought back to the laboratory for further analysis. Water samples were stored at 4°C from the time of collection until analysis, at which time the samples were allowed to warm to room temperature. Samples were generally analyzed chemically within 6 hours after they were collected.

Turbidity was determined using a Hach Model 2100A Turbidimeter, and was reported in Jackson Turbidity Units (JTU). True color was determined through centrifugation of the water samples for five minutes to remove suspended material, and subsequent measurement was made on a colorimeter. True color was reported in color units (CU). Conductivity was made on a Lab-Line Lectro-mho Meter Model MC-1, Mark IV and values are reported as micro-mhos at 25°C. Both pH and eH were measured on a Coleman Model IV pH Meter, and values reported as pH units and millivolts respectively.

Chloride, as sodium chloride was determined for water samples from collecting stations using the Mercuric Nitrate Method as described in Standard Methods (1971).

Nitrate, nitrite, ammonia, orthophosphate and sulfate were determined by colorimetric methods. Samples of unusually high turbidity were filtered prior to analysis to reduce chemical and photometric interference.

Orthophosphate was determined by the amino-napthol-sulfonic acid method, nitrate nitrogen was determined by the disazotization method, and ammonia nitrogen by the Nessler Method (Standard Methods, 1971). Sulfate concentrations in water samples were determined colorimetrically using the Turbidimetric Method outlined in Standard Methods (1971). Colorimetric determinations were done using a Bausch and Lomb spectrophotometer Model 70, and a Hach Colorimeter Model DR939BB.

Five day biochemical oxygen demand (BOD) was determined according to the methods set forth in Standard Methods (1971). Samples were normally diluted 1:3, and were incubated in the dark at 20 degrees centrigrade in a Lab-Line Incubator Model 844. Oxygen was measured before and after the five day incubation using Yellow Springs Oxygen Meter, Model 54 and a B.O.D. Probe, Model 5420A. The dilution factor was applied to the resultant oxygen change,

and the biochemical oxygen demand was reported in parts per million of oxygen per five days.

Sediment Oxygen Demand (SOD) was determined on bottom samples collected in the field, using a 0.75 inch diameter plastic core sampler. Samples were then homogenized and diluted in the laboratory. B.O.D. Bottles, filled with dilution water, were injected with one milliliter of the diluted sediment, and were incubated in the dark for 15 days at 20 degrees centrigrade with daily resuspension of solid material. Oxygen was measured as for B.O.D. The organic content of the diluted sample was simultaneously determined through ash-free-dry-weight analysis of samples of equal volume. The sediment oxygen demand is reported as parts per million oxygen per kilogram sediment per minute.

River discharge data for each station are reported in cubic feet per second and data were obtained from the United States Geological Survey in Austin, Texas.

Pesticide Methods

Collection

Samples were collected from eight stations located in the Trinity River. Each station's location is described below:

> Rosser Station: at bridge on State Highway 34 near Rosser, Texas, river mile 454 (Station #3).
>
> Highway 85 Station: At bridge on State Highway 85 near Kemp, Texas, river mile 430.
>
> Trinidad Station: at bridge on State Highway 31 near Trinidad, Texas, river mile 395 (Station #4).
>
> Cayuga Station: at bridge on U.S. Highway 287 near Cayuga, Texas, river mile 370 (Station #5).
>
> Fairfield Station: at bridge on U.S. Highway 79 near Elkhart, Texas, river mile 308 (Station #6).
>
> Highway 7 Station: at bridge on State Highway 7 near Crockett, Texas, river mile 266 (Station #7).

Highway 21 Station: at bridge on State Highway 21 near Madisonville, Texas, river mile 231.

Wallisville Station: at bridge on Interstate 10 near Wallisville, Texas, river mile 10 (Station #10).

An attempt was made to collect sediments monthly from each station from January 1972 to January 1973; however, only one sample was collected from Stations 4 and 10. In addition, water samples were collected from three deep wells near Rosser, Texas to determine if there was any significant pesticide pollution of ground water in this portion of the river basin. Location of 3 wells are on the Rosser Quadrangle, Texas, 7.5 minute series (Topographic) scale 1:2400, map supplied by the United States Department of the Interior Geological Survey. Well #1, grid coordinates 398-969 (marked 201 by U.S. Army Engineers). Well #2, grid coordinates 372-955 (marked 105 by U.S. Army Engineers). Well #3, grid coordinates 373-949 (marked 102 by U.S. Army Engineers). Water samples were collected from wells with a Kemmerer Sampler lined with Teflon.

The samples were collected in Hexane-acetone cleansed pint mason jars, by scooping up top sediment at the river's edge with a large stainless steel slotted spoon. The mason jars were filled 2/3 to 3/4 full with sediment and covered with aluminum foil and capped. At no time did collection extend further than fifty yards either side of the bridge crossing. When possible, several spots were sampled in order to achieve a more representative collection. Samples were kept on ice in an ice chest or placed in a closed cardboard box and transported back for analysis. The collected sediments were frozen at -12 degrees centigrade within twelve hours after collection.

Analysis of the earlier samples collected in the first months of the year were postponed due to delays in receiving the supplies needed for their analysis. For this reason many of the samples were kept frozen as long as eight months. Samples were allowed to thaw in a refrigerator at 7.5 degrees centigrade prior to analysis. The samples were then removed from the refrigerator and stirred to achieve homogeneity.

Extraction

One hundred and fifty grams of undried sediment were weighed and placed in a five hundred milliliter glass stoppered erlenmeyer flask. A three hundred milliliter mixture of 4:1 hexane isopropanol was poured into the flask along with one hundred grams of anhydrous sodium sulfate. The sample was then extracted using a wrist-action shaker for a period of four hours.

The extract was then filtered into a five hundred milliliter separatory flask equipped with a Teflon stopcock. One hundred milliliters of deionized water was then added to the extract and shaken for two minutes. The mixture was allowed to separate and the aqueous layer drawn off and discarded. This was repeated three times to remove the alcohol from the extract.

Clean-up of the sample was done by allowing the extract to pass through a column (one cm i.d.) made of a silanized glass woolplug, six grams of hexane-rinsed activated Florisil and two grams of hexane-rinsed anhydrous sodium sulfate, in that order. The extract was then allowed to pass through the column at a rate of about two milliliters per minute. After measuring the volume of the eluant, the column was rinsed with an additional fifty milliliters of hexane.

The eluant and rinsings were transferred into a three-neck distilling flask. Into one neck was placed a column containing activated silica gel. The middle was glass stoppered and the third contained a vacuum connecting tube. The sample was concentrated by pulling a stream of dry air over the solution at a reduced pressure.

The volume of the concentrate was determined and then transferred into a twenty-five milliliter vial with a Teflon lined screwcap. The concentrate, which had been adjusted to twenty milliliters, was stored at 7.5 degrees centigrade in the dark until analysis could be made.

Care was taken to avoid introducing substances that would interfere with the pesticide analysis. This was accomplished by running extensive controls before beginning analysis. Chemicals were kept in five gallon drums so that assumptions to its quality could be made. Fifty percent of the samples were run using analyzed reagent grade solvent, and the other samples were run using pesticide grade solvent. After the initial controls, a control was run

every tenth extraction. The Florisil and sodium sulfate were heated to 550 degrees centigrade for two hours and then dessicated until use.

Percent dry weight was determined by transferring 100.0 grams of the wet sediment to a porcelain crucible and placing it in a drying oven at 105 degrees centigrade for six hours. The sample was allowed to cool in a dessicator and weighed. A two to ten gram portion of the dried sediment was weighed on an analytical balance and then placed in a muffle furnace at 550 degrees centigrade for four hours to determine the percent organics, by loss on ignition. A fifty gram portion of the dried sediment was used to determine percent sand, silt and clay by the Bouyoucos Hydrometer Method (Bouyoucos, 1962). This technique utilizes the differential settling rate of the soil particles according to particle size. Dispersed sand (between 2.00 - 0.05 mm), silt (between 0.05 - 0.0002 mm) and clay (less than 0.0002 mm) [1] left in suspension is measured using a Bouyoucs Hydrometer which has been corrected for the suspension's temperature.

Sulfur was found to be present in a large percentage of the samples extracted. Sulfur interferes with Heptachlor, Aldrin, Lindane and Chlordane and must be removed before analysis can be attempted. Schutzmann, Woodham and Collier (1971) describe a method for removing up to 50 ppm elemental sulfur by refluxing with a copper-aluminum alloy. Although this method is efficient, supplies for the extraction could not be received in time for completion of analysis. Goerlitz and Law (1971) propose a technique used in this study in which metallic mercury is introduced to the extract to precipitate out the sulfur. Removal of a large percentage of the elemental sulfur was found within ten minutes, and analysis in most cases could proceed. In several cases all sulfur could not be removed, and the co-extractive interferences remained present.

Percent recovery was determined by extracting the same sediment repeatedly until no pesticide could be detected. Recovery on first extraction ranged from eighty-two to ninty-seven percent. The percentage of mud extracted was determined by assuming that the fraction of hexane recovered represented the proportion of actual mud extracted. The sediment's weight was then adjusted to its actual dry weight by using the percent dry weight previously determined. The concentrations reported in micrograms pesticides per kilogram dry sediment weight were not corrected for percent pesticide recovered. Confirmation

was made using a second column containing 2.5% DC-200 and 2.5% QF-1 liquid phase. Further confirmation of residues' identity was not made due to a lack of time and facilities.

Determination of Residues

Determination of the cleaned extract was accomplished using a Varian-Aerograph 2100 gas chromatograph equipped with a Nickel 63 electron capture detector. The glass column (1/4 inch o.d. By 6 feet) was packed with 5% QF-1 liquid phase on 80-100 mesh Chromosorb W. Nitrogen flow rate was 60 ml per minute. Injection temperature at 200 degrees centigrade, and detector temperature injection volume ranged between 0.6 microliters to 4.0 microliters. No pesticidal quantities are reported for organic chlorine compounds less than 0.2 micrograms per kilogram, except for chlordane whose lower detectable limits are set for 1.0 micrograms per kilogram.

Dissolved and Particulate Organic Carbon Analytical Methods

Water samples were collected from each station monthly. Samples were collected at the surface in 30 ml glass vials and within six hours, the samples were stored in a deep freeze until they were analyzed.

Oceanography International Total Carbon System Model 0524A was used to analyze water samples for total carbon (organic carbon plus carbon in carbonates) and inorganic carbon (i.e., carbonate).

Frozen water samples prior to filtering were allowed to thaw at room temperature. Each water sample was filtered through a pre-combusted Gelman Type A glass fiber filter for the partitioning of POC and DOC. Aliquots of the filtrate were analyzed for DOC, and for POC. The DOC and POC were determined by modifications of the method developed by Menzel and Vaccaro (1964), Fredericks and Sackett (1970), and Brooks (1970). A step by step description of this method is listed below:

(1) Thirty ml water samples were frozen in glass vials until time permitted filtering and sealing.

(2) Ten ml glass ampules (Owens-Illinois) were prepared for use by being tapped upside down on a clean surface (to remove any particles of foreign material) and the top of

the neck of the ampule wrapped with a piece of lightweight (one inch square) aluminum foil twisted to form a cover for the ampule. Ampules were pre-combusted at 550°C for four hours.

(3) Gelman Type A (0.3 micron) glass fiber filters (25 mm diameter) were pre-combusted at 400°C for four hours. Filters were handled only with clean forceps.

(4) Frozen water samples were allowed to thaw at room temperature prior to filtering and sealing.

(5) Four pre-combusted glass ampules were required for each water sample; giving replicate analysis for DOC and POC. To each ampule 0.2 grams of potassium persulfate and 0.25 ml of 6% phosphoric acid solution were added prior to addition of the sample.

(6) Before filtering, samples were briskly shaken and aliquots removed by syringe.

(7) Three ml aliquots of water sample were taken into two syringes through millipore lock-on syringe filter holders containing pre-combusted Gelman glass fiber filters.

(8) The two filters (each containing 3 ml POC from the 3 ml aliquots) were air dried with a water aspirator and inserted in ampules. Distilled water (5 ml) was then added to each POC vial.

(9) two ml aliquots of filtrate were then added from the syringe to the two ampules for DOC analysis.

(10) Filled ampules were purged of inorganic carbon constituents for four to six minutes with purified oxygen flowing at a rate of 60 ml/min, and then sealed in a special apparatus (designed by Oceanography International Corporation, College Station, Texas) to prevent CO_2 contamination from the sealing flame.

(11) Sealed ampules were eated at 125°C for four hours in an autoclav· to oxidize organic carbon to carbon dioxide.

(12) The carbon dioxid content of each ampule was then analyzed in a special ampule breaking apparatus (designed by Oceanography International Corporation, College Station, Texas) which permits the carbon dioxide to be flushed through an infrared analyzer.

The carbon dioxide content of each ampule was determined by flushing the gas content of the ampule with nitrogen into the gas stream of a non-dispersive infrared analyzer sensitized to carbon dioxide. The detector output of the analyzer was recorded as a peak on a potentiometric strip chart recorded equipped with an integrator.

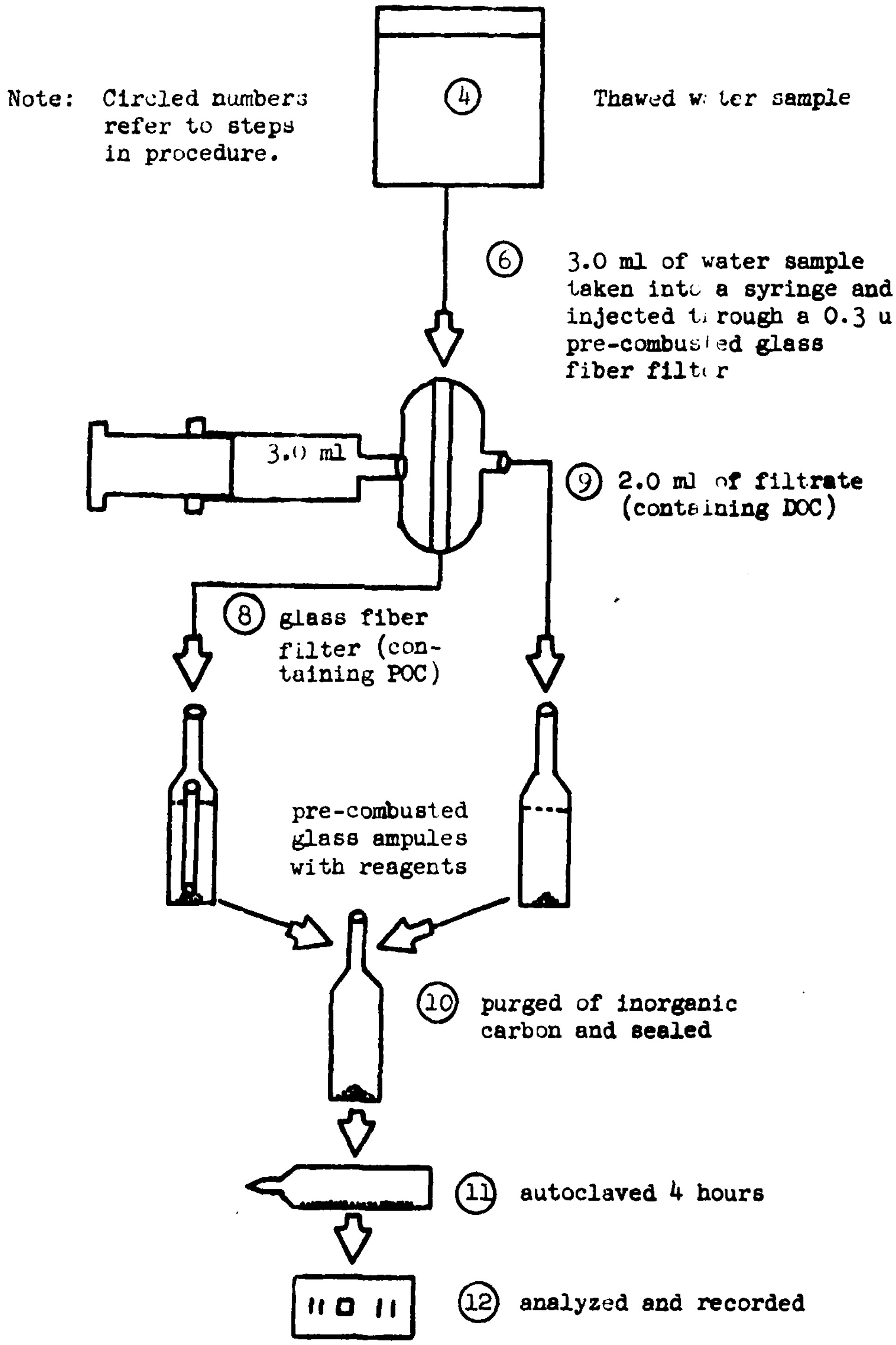
Standard carbon dioxide conversion graphs were made by plotting the integrated area versus carbon for standardized sodium carbonate solutions. The standard was made by injecting a known volume of the sodium carbonate standard through a rubber septum in a special vial containing phosphoric acid solution. The organic carbon concentration (those organic carbon compounds oxidized by persulfate and heat to carbon dioxide) of each ampule was determined by comparing the integrated area to the standard carbon dioxide conversion graph.

The deviation for duplicated DOC determinations on the same water sample was generally 5% or lower, with POC usually 10% or lower. A reagent blank value was determined with each set of water samples sealed. The DOC reagent blank value varied from 0.003 mg C to 0.004 mg Cl. The POC reagent blank value varied from 0.003 mg C to 0.006 mg C.

<u>Phytoplankton Methods</u>

Standing crop of phytoplankton was based on collection of surface water samples at each station from September 1972 through April 1973. Concentration of samples for cell counts was accomplished by passing one liter of each water sample through a FOERST electrical plankton centrifuge three times (Hartmann, 1958). The volume of the concentration was then determined. Cell counts were done using a phase contrast compound microscope and hemacytometer. Direct microscopic counts of phytoplankter were expanded to cells per liter by the equation given in Welch (1948).

Flow chart for organic carbon analysis (DOC & POC)



Periphyton Methods

Periphyton samples were collected by allowing organisms to colonize submerged artificial substrates according to techniques suggested by Sladeckova (1962) and Sladecek and Sladeckova (1963). The periphyton samples were placed at each collecting station and consisted of a plastic float supporting a wooden slide rack constructed according to the directions given in Welch (1948). The slide racks were submerged two inches from the surface and the slides were held with the long axis parallel to, and their short axis perpendicular to, the water surface. The slides were collected at two week intervals and replaced with clean slides. Weber and Raschke (1970) report that a two week exposure period is sufficiently long to permit development of abundant periphyton yet is short enough to reflect short term changes in water quality. The periphyton was scraped from the slides, diatom frustules cleaned and mounted in hyrax on slides for microscopic examination. Frustules were examined under oil immersion, 1000 magnification, with a phase contrast microscope. Each sample was evaluated by identifying 100 diatoms to species on each slide. Individuals were selected by a transect method. These data were then used to calculate the diversity indices utilizing a Model 720 Wang computer.

The mathematical expression of the ratio between numbers of species and individuals in a biotic community is referred to $_s$ as a diversity index (Odum, 1959). The equation: $d = \sum_{i}^{s} (n_i/n) \log_2 (n_i/n)$ reported by Wilhm and Dorris (1968) as a measure of diversity (or information) per individual was used where "n" is the number of individuals in "S" species, and "n_i" is the number of individuals in the i'th species with logarithms interpreted to base 2. Warren (1971) reports that reductions in community diversity can be used as an index of environmental change such as the introduction of domestic or industrial effluents into an aquatic ecosystem. In this study, diversity index values were used as an index of pollution.

One slide rack was located at each collection station except Station 10. In an attempt to assess the biological impact of the effluent from the Texas Gulf Sulfur plant on the Trinity River. One slide rack was located three hundred yards downstream from the outfall and another was placed three hundred yards upstream from the outfall.

Slides were collected and species diversity determined according to directions previously alluded to.

Chlorophyll Analytical Methods

Chlorophyll *a*, *b*, and *c* concentrations were determined from phytoplankton water samples collected at each sampling station. A 100 ml aliquot of the phytoplankton sample was filtered through a millipore filter type HA with 0.45 micron pores. The concentration of chlorophyll *a*, *b*, and *c* was subsequently determined by the technique described by Richards and Thompson (1952) with revised equations by Parsons and Strickland (1964). Optical density values were determined using a Coleman Universal Model 14 Spectrophotometer.

Primary Productivity Methods

The rate of primary productivity was determined for each station using the Diurnal Oxygen Curve Method for flowing waters as reported in Standard Methods (1971). The grams of O_2/m^3 and °C was determined at each meter of depth every three hours for 24 hours. The last measurement was taken at the same time the first measurement was taken. The measurements were made on the "halfmeter", assuming the D.O. And °C at 0.5 meters are the average values for the layer of water between 0.0 and 1.0 meters. The community metabolism values were calculated according to the equations in Standard Methods (1971). Assuming that for every gram of oxygen produced there is approximately one gram of organic matter produced.

$$6CO_2 + 12H_2O \xrightarrow[\text{Chlorophyll } \underline{a}]{\text{Sunlight}} C_6H_{12}O_6 + 6O_2 + 6H_2O$$

The rate of change in the concentration of dissolved oxygen in grams per cubic meter is:

$$q = p - r + d_{in.} + a$$

where (q) in the rate of change in O_2/m^3, (p) is the rate of photosynthesis, (r) respiration rate, (d) is the diffusion rate, and (a) is the accrual from ground water inflow and runoff.

The rate of change in oxygen in a one square meter water column is determined by taking the sum of the rates of change for each meter of depth.

$$q_z = \sum_{1}^{z} (p - r + d_{in.} + a)$$

The diffusion rate of oxygen into the water (D) is determined by multiplying the gas transfer coefficient (K) and the percent saturation deficit (S).

$$D = KS$$

(D) is the diffusion rate in g $O_2/m^2/hr$ and (K) is based on the diffusion rate at zero percent saturation.

The gas transfer coefficient (K) is calculated by the following equation:

$$K = \frac{q_m - q_e}{S_m \quad S_e}$$

where (q_m) is the average negative rate of change during the morning hours before sunrise, (q_e) is the average negative rate of change during the evening hours after sunset, (S_m) is the saturation deficit in the morning hours before sunrise and (S_e) is the saturation deficit in the evening hours after sunset.

Gross productivity, community respiration, and net productivity in g $O_2/m^2/day$ were calculated.

Milligrams of O_2 produced was converted to milligrams of carbon by the equation reported by Strickland (1966):

Carbon assimilated by photosynthesis in mg per unit time =

$$(\text{mg } O_2 \text{ evolved in unit time}) \times \frac{0.375}{PQ}$$

A PQ (photosynthetic quotient) of 1.2 was used.

<u>Benthic Methods</u>

At the site of collection one Ekman dredge grab (1/25 sq. Meter) was passed through a bucket with a double-screened bottom and the contents retained for laboratory examination. After removal of any visible macroinvertebrates, this sample was filtered through two to six of a series of screens of graduated mesh sizes 10 to 230. Contents of each screen were placed in pans or in petri dishes for microscopic examination, with the exception of molluscs, which were retained in plastic bags or in water. Invertebrates were counted and preserved in FAA (formalin-aceto-alcohol) (Pennak, 1953) for later identification.

A diversity index figure for each sample taken was calculated by the formula $\bar{d} = -\sum_{1}^{s}(n_i/n) \log_2 (n_i/n)$ (Wilhm and Dorris, 1968). For this purpose, organisms were separated into as many different species as possible.

Zooplankton Methods

Zooplankton collected in one five-minute horizontal plankton tow with a #25 bolting cloth plankton net was retained for laboratory examination. After brief observation of living organisms beneath both dissecting and compound microscopes, the plankton was preserved in FAA (formalin-aceto-alchhol) (Pennak, 1953). Three one-milliliter portions of each homogeneously mixed sample were identified and counted in a Sedgewick-Rafter cell under the compound microscope at 10X power. By the use of an average value for each organism in the three milliliters and the total number of milliliters in the sample, extrapolation produced the estimated total number of each organism in the five-minute plankton tow.

A diversity index ($\bar{d}$) figure for each sample taken was calculated by the formula $\bar{d} = -\sum_{1}^{s}(n_i/n) \log_2 (n_i/n)$ (Wilhm and Dorris, 1968). For this purpose, organisms were separated into as many different species as possible. Also, numbers of ephippia were added to cladocera numbers, nauplii to copepods, and dipteran pupae to dipteran larvae before calculation of $\bar{d}$.

Bacteriology Methods

The methods involved in this study will include the Millipore technique and the multiple tube fermentation methods. These techniques will give an estimate of the number of total coliform, fecal coliform and fecal streptococcus per 100 milliliters of water sample. The sampling procedure involved collecting a 200 milliliter surface water sample in a sterile 250 milliliter erlenmeyer flask. The samples were immediately placed in refrigeration at 4°C and returned to the laboratory for analysis.

Methods I
(Preparation of media used in MPN and membrane filter analysis)

The lactose fermentation media used in the most probable number determination was prepared by using 7.5 grams of lactose, 16 grams of phenol red broth base and 1

liter of distilled water. The lactose media was then pipetted into test tubes in nine milliliter portions. The durham tubes were autoclaved for fifteen minutes at 121 degrees centigrade. The lactose tubes were then stored at 4 degrees centigrade for not more than thirty days.

Eosin methylene blue plates were used on the confirmatory step on the most probable number analysis. The media was prepared using the directions on the bottled dehydrate. The plates were stored in plastic bags at 4 degrees centigrade for period not to exceed thirty days.

The completed step utilized the above mentioned lactose preparation and nutrient agar slants which were prepared following the directions on the bottled dehydrate. The nutrient agar media was pipetted into test tubes and autoclaved for fifteen minutes at 121 degrees centigrade. The tubes were removed from the autoclave and slanted until the media solidified. The slants were then stored at 4 degrees centigrade.

Three media were used in the membrane filter analysis. These included m-Endo-MF broth for total coliform, m-FC broth for fecal coliform, and m-enterococcus agar for fecal streptococcus. Autoclaved 250 milliliter erlenmeyer flasks with cotton plugs were used for preparation of 100 milliliters of distilled water measured in an autoclaved graduated cylinder. Two milliliters of 95% ethyl alcohol were added to the water in the graduated cylinder. The contents were then poured into the flask containing the m-Endo-MF broth dehydrate. The flask was then removed, and the media allowed to cool. If the media was not used immediately, then it was refrigerated for a maximum of ninety-six hours.

The m-FC broth was prepared by weighing out 3.7 grams of dehydrated media and placing it in an autoclaved 250 milliliter flask. One hundred milliliters of distilled water were measured in an autoclaved cylinder and added to the dehydrate in the flask. One milliliter of 1% rosolic acid was added to the dissolved broth. The flask was then heated in a 100 degree centigrade water bath until the media began to boil. The media was then allowed to cool to room temperature. If it was not used, it was stored at 2-10 degrees centigrade for a maximum of ninety-six hours.

The m-enterococcus agar dehydrate involved weighing 4.2 grams of media and placing it in an autoclaved flask. One hundred milliliters of distilled water was added, and

the flask was placed in a 100 degree centigrade water bath where the liquid was heated to boiling. The liquid agar was then cooled to 45-50 degrees centigrade and dispensed in six milliliter portions into the bottom half of a petri dish with a diameter of 60 milliliters. These plates may be stored in the dark for thirty days at 2-10 degrees centigrade.

Methods I
(Preparation of media used in classifying fecal coliform and fecal streptococcus)

The remaining media employed in this study were made according to directions on the bottled dehydrate. An effort was made to utilize all media before thirty days had elapsed. The media used will be mentioned in Methods II section on classification of organisms.

Methods I
(Preparation of materials used in most probable number and membrane filter analysis)

Dilution blanks were prepared in test tubes containing nine milliliters of distilled water and in dilution bottles containing ninety-nine milliliter portions of distilled water. These dilution blanks were autoclaved for fifteen minutes at 121 degrees centigrade. The blanks were then refrigerated.

Stock phosphate buffer solution was prepared by dissolving 43.0 grams of potassium dihydrogen phosphate in an autoclaved two liter erlenmeyer flask. This flask was then filled with 500 milliliters of distilled water. The pH was adjusted to 7.2 with 1 N sodium hydroxide, and this material was diluted to one liter with distilled water. This stock was stored in the dark at 4 degrees centigrade. Five hundred milliliter portions of distilled water were placed in one liter flasks and these portions were autoclaved. Upon preparation for water analysis these 500 milliliter portions were removed from the refrigerator, and .625 milliliters of stock buffer solution was pipetted into the distilled water. The pH on the stock buffer solution was checked before it was used. The stock buffer solution was prepared on a monthly basis. The phosphate buffer water was used as a rinse on the membrane filter apparatus (Millipore Manual AM302, p. 21).

The membrane filtration apparatus was prepared for use prior to the analysis of each set of water samples. The

glassware such as pipettes, flasks, and filtering apparatus were rinsed thoroughly with distilled water prior to autoclaving. The sampling flasks are periodically rinsed with a dichromate solution followed by several distilled water rinses. The side arm flasks were plugged with cotton and autoclaved. The filter support and funnel are individually wrapped in Kraft paper. These were autoclaved prior to the actual filtration.

Methods II

The actual procedural methods used in this study were the Millipore technique and multiple tube fermentation method.

A. Multiple tube fermentation method (*Standard Methods for Examination of Water and Wastewater*, 1971).

1. Dilutions from 10^1 through 10^6 are made on each sample using 9 milliliter water blanks. These dilutions are made after thorough agitation of the water sample

2. A three milliliter portion is then pipetted from each dilution blank. One milliliter is placed in each of a series of three lactose tubes for the particular dilution. A set of eighteen lactose tubes is required for each sample.

3. The tubes are incubated for 48 hours at 37 degrees centigrade and examined for acid and gas formation.

4. The highest dilution showing acid and gas production is streaked on an eosin methylene blue plate and checked after 24 hours for a green metallic sheen.

5. The colony showing a green metallic sheen is streaked on a nutrient agar slant, and after growth is reinoculated into lactose broth to be evaluated for acid and gas formation.

6. The nutrient agar slant growth is Gram stained after 18-24 hours. If the organism was Gram negative and produced acid and gas in lactose, the evidence indicated the presence of *Escherichia coli*.

B. Membrane filter technique (Millipore Manual AM 302, 1972). The dilutions used on the membrane filter were varied among stations. In order to try to obtain the suggested range of colonies on total coliform (20-80), fecal coliform (20-60), and fecal streptococcus (20-100), it was necessary to try several dilutions on one station. In the procedure following, this fact should be emphasized. Generally 1:10, 1:100, and 1:1000 dilutions were run, and three plates set up for each analysis.

1. The broth media used in membrane filter technique was brought to room temperature. Sterile 60 millimeter petri dishes were opened using the end of flamed forceps. The absorbent pads were then added to the petri dishes in a series of plates necessary for analysis of the water sample. The pads were placed in the smooth half of the petri dish. Two milliliters of prepared broth were pipetted into each petri dish. A series of three plates was set up for each dilution of the total coliform and fecal coliform analysis which involved liquid media.

2. The agar plates were also removed and allowed to reach room temperature before the filtration was initiated.

3. The vacuum pump and the filtration apparatus was retained on the Kraft paper, mouth down. The funnel was attached and the pump turned on for five minutes.

4. The excess alcohol was burned off the forceps and one sterile filter (0.45 m) was carefully transferred to the filter holder. The filter was centered with the grid side up. The forceps were replaced in the alcohol, and funnel was placed on top of the holder base and over the membrane filter. The filtering funnel was secured with a clamp.

5. The sample was agitated prior to filtration in each of several dilutions set up on each analysis. A sample volume of 10 milliliters for each dilution series was then pipetted into the filter funnel, and this volume was followed by a 20 milliliter rinse of buffer water. The buffer rinse was repeated twice with the buffer solution poured down the side of the funnel so that a

swirling action resulted.

6. The medium-containing petri dish was obtained and the filter was placed on the absorbent pad or agar depending on which step of the analysis was being done.

7. The dilutions used in the membrane filter analysis were prepared before filtration and were not used if more than thirty minutes had elapsed.

8. Incubation was begun as soon as one complete sample was finished.

9. Total coliform analysis involving m-Endo-MF broth were incubated for twenty-four hours at 37 degrees centigrade and examined for colonies illustrating a green metallic sheen under a dissecting scope with a light source attached. The fecal coliform analysis utilizing m-FC broth was incubated for twenty-four hours in a 44 degree bath. The colonies with a blue color were counted. The fecal streptococcus analysis involving m-enterococcus was incubated for forty-eight hours at 37 degrees centigrade, and the colonies illustrating a red color were counted.

10. The results were recorded and the ratio between fecal coliform and fecal streptococcus was then calculated in an effort to determine the source of contamination.

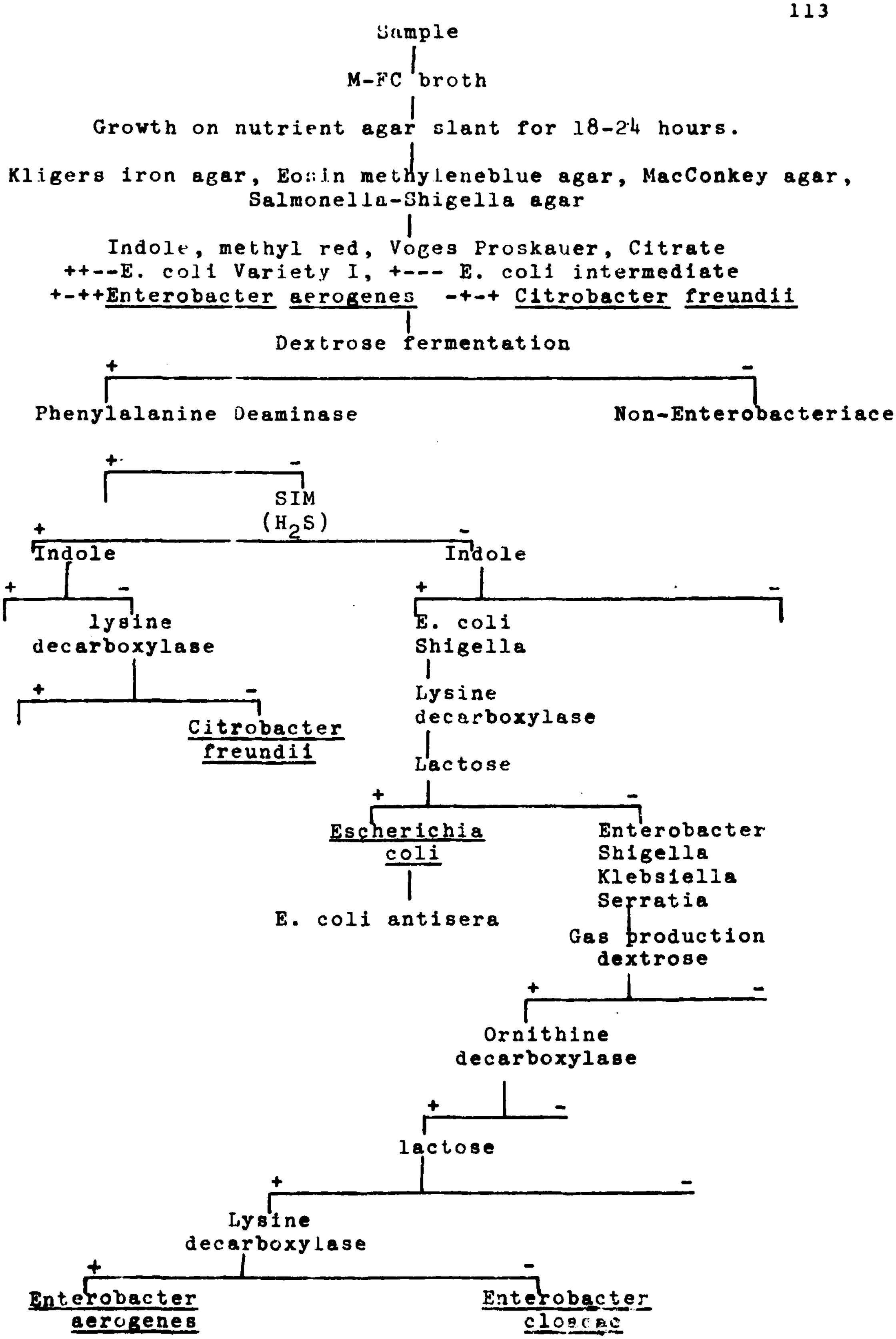
C. Classification of fecal coliform and fecal streptococcus.

1. An isolated colony is picked up from fecal coliform or fecal streptococcus plate and transferred to a nutrient agar slant. These slants were incubated for 18-24 hours, and Gram stains were done to determine gram negative or gram positive.

2. The gram negative organisms which were isolated from the fecal coliform plates were streaked on eosin methylene blue plates, MacConkey plates, and Salmonella-Shigella agar plates. The next series of tests

involved inoculation of the organism into indole media, methyl-red-Voges Proskauer media, and citrate tablet test. The organisms were also inoculated into Klingers iron agar slants, dextrose fermentation media, SIM tubes,and urea media. This combination of media was then incubated for twenty-four hours at 37 degrees centigrade. A new culture was also inoculated on several nutrient agar slants. Dextrose fermentation media, ornithine tablet test, lysine decarboxylase tablet test, phenylaline deamisse tablet test, and lactose fermentation media were also used. Aseptic technique was used in an effort to lower the possibility of contamination.

3. The gram positive organisms which were isolated from the fecal streptococcus plates were transferred to trypticase soy agar slants. Gram stains were done on these cultures after 18-24 hours growth at 37 degrees centigrade. The organisms were then transferred to brain heart infusion broth for two days at 10 degrees centigrade. The organisms were also inoculated into 40% bile broth and examined for growth. The organisms were then checked for catalase reaction. Two temperatures (45 degrees and 10 degrees centigrade) were then employed to check for growth. The one that grew at both temperatures were confirmed with growth in 6.5% sodium chloride in brain heart infusion broth. The next step involved streaking the organisms (those that grew at both 45 and 10 degrees centigrade and those that grew only at 45 degrees) onto a starch agar plate. The streptococci that grew at 45 degrees centigrade only were then transferred into lactose fermentation media to check for acid reaction after twenty-four hours incubation. The organisms that grew at both temperatures were placed in litmus milk for the final step of analysis. After incubation, the litmus milk cultures were checked for peptonization. (Geldreich and Kenner, 1969).


Sample
M-FC broth
Growth on nutrient agar slant for 18-24 hours.
Kligers iron agar, Eosin methyleneblue agar, MacConkey agar, Salmonella-Shigella agar
Indole, methyl red, Voges Proskauer, Citrate
++--E. coli Variety I, +--- E. coli intermediate
+-++Enterobacter aerogenes -+-+ Citrobacter freundii
Dextrose fermentation
+
-
Phenylalanine Deaminase
Non-Enterobacteriace
+
-
SIM
(H_2S)
+
-
Indole
Indole
+
-
lysine decarboxylase
+
-
Citrobacter freundii
+
-
E. coli
Shigella
Lysine decarboxylase
Lactose
+
-
Escherichia coli
E. coli antisera
Enterobacter
Shigella
Klebsiella
Serratia
Gas production dextrose
+
-
Ornithine decarboxylase
+
-
lactose
+
-
Lysine decarboxylase
+
-
Enterobacter aerogenes
Enterobacter cloacae

SAMPLE

(m-Enterococcus agar)

Pink-red colonies

Growth in brain-heart infusion broth within 2 days at 45 and 5 days at 10 C with confirmation as catalase-negative and positive for growth in 40% bile broth

Growth at 45 and 10 C

Confirm with growth in 6.5% NaCl in brain-heart infusion broth

Lancefield group D Streptococci

Starch hydrolysis

Positive — A typical *S. Faecalis* (Vagetation source)

Negative

Peptonization of litmus milk

Positive — *S. faecalis* var. liquefaciens (Insect source)

Negative — Enterococci (Warm-blooded animal sources)

Growth at 45 C only

S. bovis - *S. equinus*

Starch hydrolysis

Positive

Lactose fermentation

Acids only — *S. bovis*

No change — *S. equinus*

(livestock and poultry sources

RESULTS AND DISCUSSION

Water Quality

The results of water quality analysis may be found in Appendix III-01 and in Figures III-01,02,03, and 04. Oxygen is perhaps the single most important parameter that a limnologist can measure in any aquatic environment. Oxygen values on the Trinity River varied from a minimal average of 4.7 parts per million at Station 3 to a maximal average value of 10.4 parts per million at Station 8. In general, oxygen tends to increase gradually from Station 3 downstream to Lake Livingston. Below Lake Livingston, oxygen values are significantly higher than values encountered on the upper river. This increase in oxygen below Lake Livingston reflects increased water quality which will also be reflected in other parameters yet to be discussed. The high value of 10.4 parts per million at Station 8 suggests two possible explanations. (1) There may be fewer organics present in the water at Station 8, most of these having been broken down and utilized by organisms in Lake Livingston (as seen by the eutrophic state of the upper region of the lake), or having been settled out as sediment. (2) also the release of water at the Livingston Dam may in itself serve to oxygenate the water as a result of tumbling down the "release way". Once below the dam and Station 8, organics may again increase, resulting in the observed decrease from 10.4 parts per million at Station 8 to 8.8 parts per million at Station 10. The depression of oxygen at Station 10 may also result from high chlorides. Similarly, up river, oxygen decreases from Station 1 to Stations 2 and 3 are due primarily to the excessive input of organic matter from domestic sewage from the metropolitan Fort Worth-Dallas area. Upstream from Station 1, the Trinity River receives effluents from two major sewage treatment plants, Fort Worth Riverside and Fort Worth Village Creek and effluents from two major industries, Fort Worth Refining Company and the American Manufacturing Company. Downstream from Station 1, the effluents from four major sewage treatment plants are received, the TRA Central, Dallas White Rock, Dallas and Dallas South Side, while the effluents of one major industry is received, Proctor and Gamble Incorporated. (Forrest and Cotton, 1970). White Rock Creek receives the effluents from the Richardson sewage treatment plant and forms a confluence with the Trinity River upstream from Station 2. The East Fork of the Trinity River is also the source of a considerable in-put of organic enrichment, with one of the major sources coming from Garland-Duck Creek producing an average sewage discharge of 9.80 (mgd).

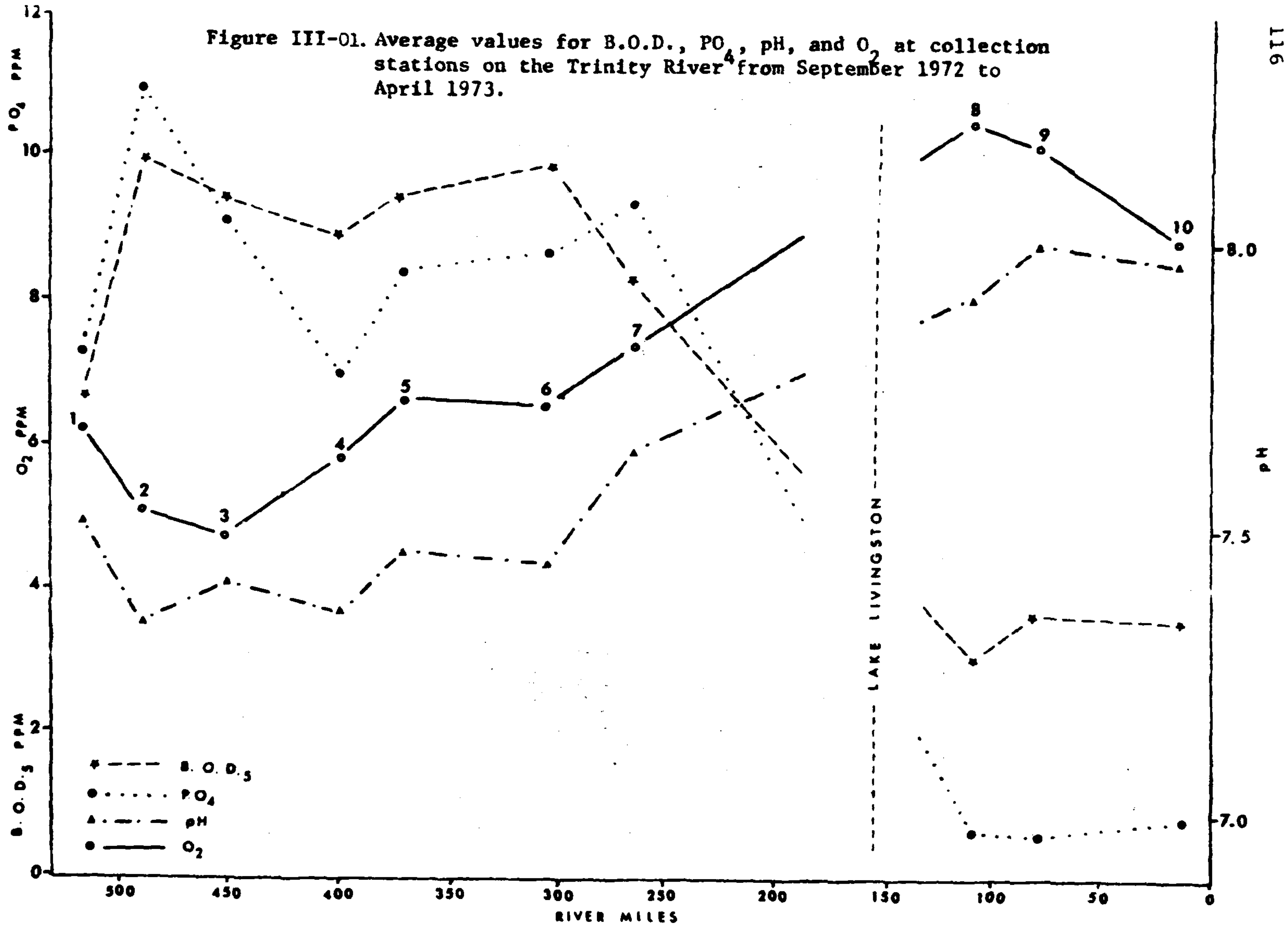


Figure III-01. Average values for B.O.D., PO_4, pH, and O_2 at collection stations on the Trinity River from September 1972 to April 1973.

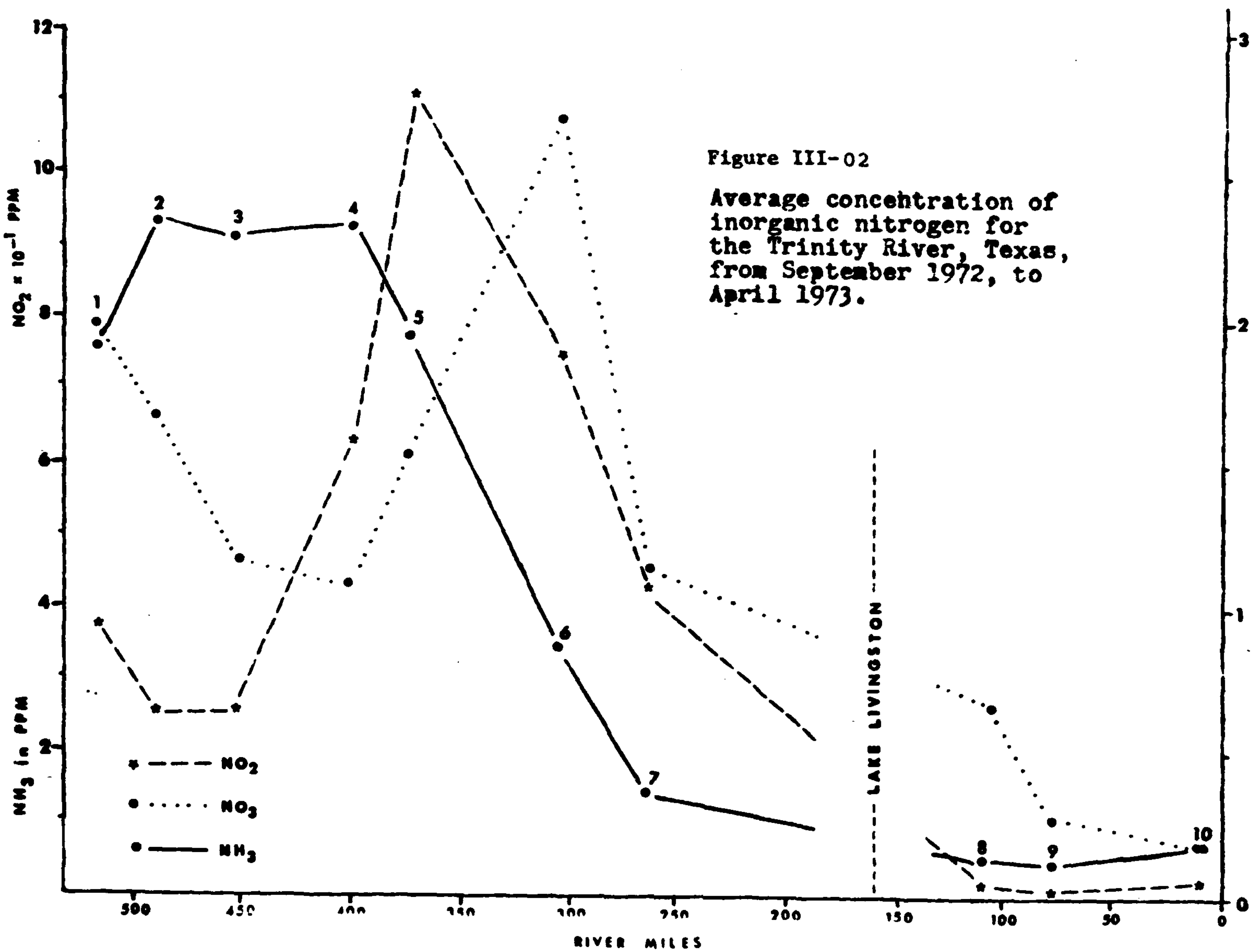


Figure III-02

Average concentration of inorganic nitrogen for the Trinity River, Texas, from September 1972, to April 1973.

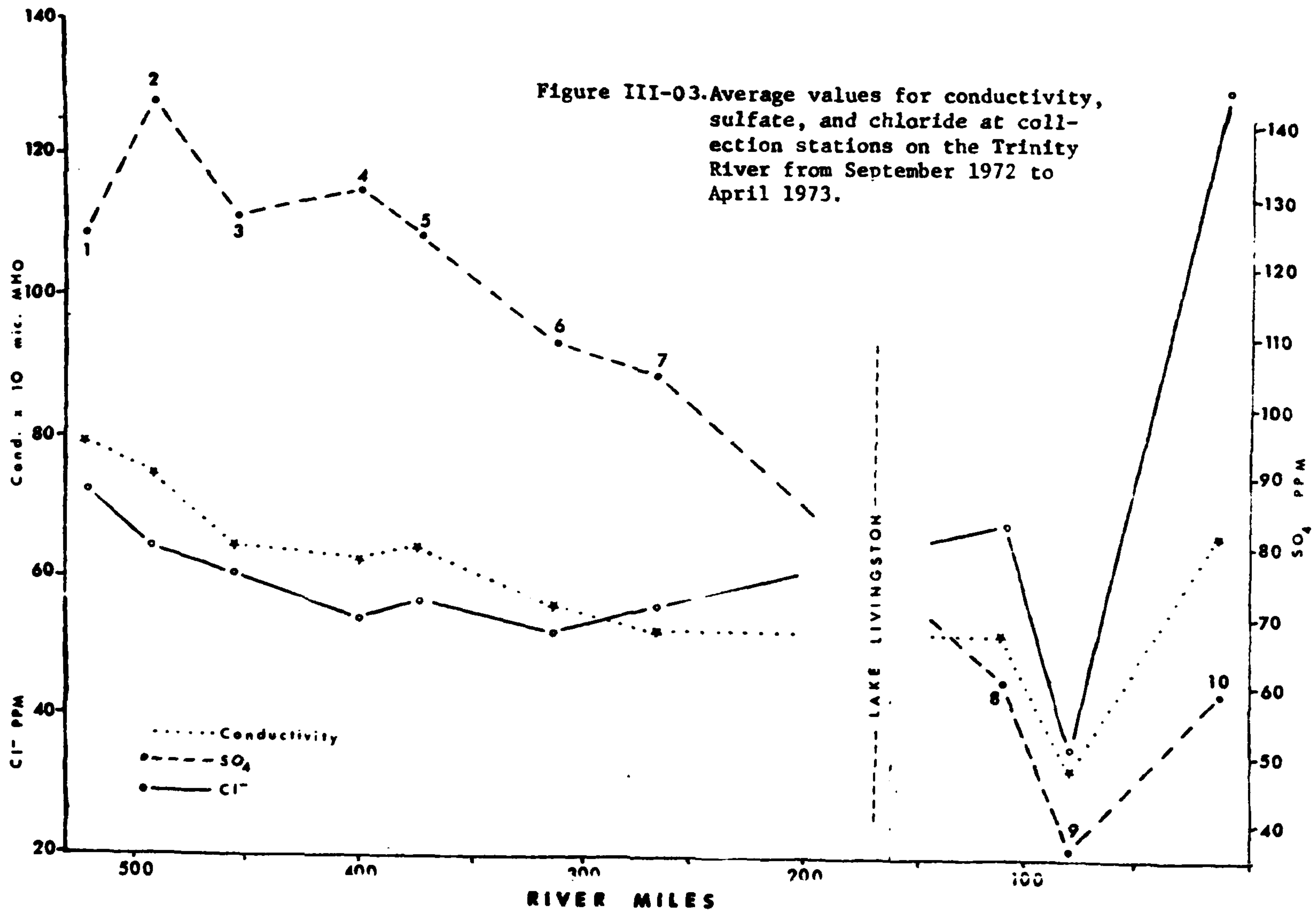


Figure III-03. Average values for conductivity, sulfate, and chloride at collection stations on the Trinity River from September 1972 to April 1973.

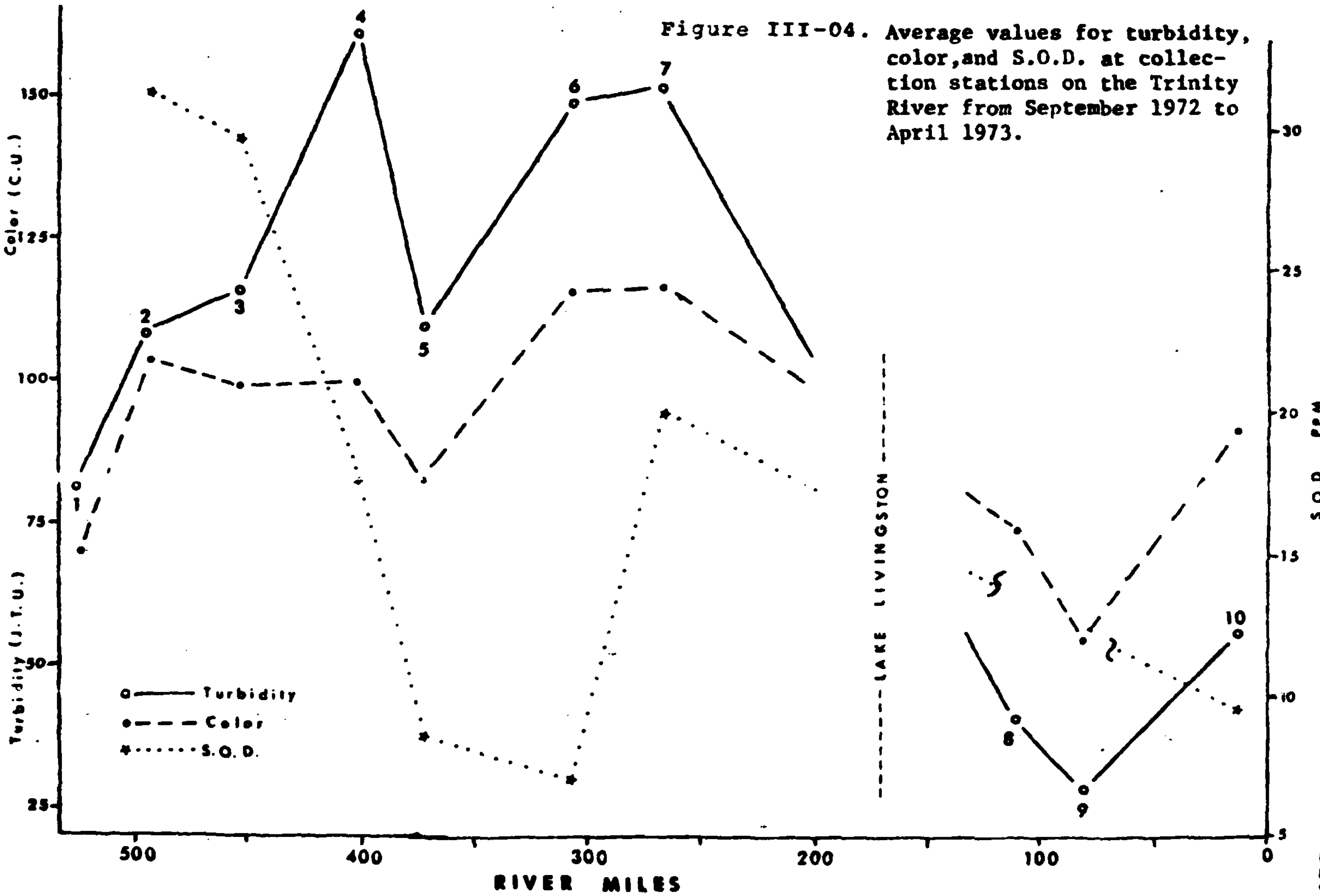


Figure III-04. Average values for turbidity, color, and S.O.D. at collection stations on the Trinity River from September 1972 to April 1973.

The influence of organic enrichment on dissolved oxygen is borne out well by the relationship between oxygen concentrations and biochemical oxygen demand (BOD_5) at each station. Generally, BOD_5 is high above Lake Livingston with a maximum average of 9.9 parts per million at Station 2. Below Lake Livingston BOD_5 values drop significantly, showing a minimum average of 2.9 parts per million at Station 8, again indicating the removal of organics occurring in the lake. Where plotted together, oxygen and BOD_5 show an inverse relationship to be highly significant with a correlation coefficient of r = -0.9045.

Orthophosphate also shows some interesting trends. Orthophosphate shows a maximum average of 10.94 parts per million at Station 2, and a minimum average of 0.54 parts per million at Station 9. Plotting BOD_5 against orthophosphate indicates that these parameters are also closely related, and simple linear regression showed this relationship to be significant with a correlation coefficient of r = +0.9436. The fact that BOD_5 and orthophosphate are closely related suggests that phosphate is being introduced into the river as domestic pollution as opposed to agricultural and industrial pollution. The high rate of overturn of phosphorus and its conversion from organic to inorganic forms may invalidate this suggestion, however. Fecal coliform to fecal streptococcus ratios for Stations 1 through 7 are greater than 4.0 which indicates human sewage as opposed to pasture or feedlot contamination.

NIPAK, Inc.,a fertilizer plant located near Station 4 did not appear to have any influence on orthophosphate, with a significant decrease in concentration between Station 3 and 4.

Orthophosphate also is inversely related to oxygen (r = -0.9024). This relationship may be real and significant if a high phosphate value triggers high bacterial populations and a resultant high oxygen demand. Hayes and Phillips (1958) have shown that bacteria take up large quantities of inorganic phosphorus. On the other hand, the relationship of orthophosphate and oxygen may merely be coincidental to the more elementary relationships of phosphate to BOD_5 and BOD_5 to oxygen. It is also interesting to note, from the tremendous decrease in orthophosphate from Station 7 (9.42 parts per million) to Station 8 (0.56 parts per million), that there must be a significant uptake and utilization of phosphorus in Lake Livingston and this is probably having a marked effect on the eutrophication of the reservoir.

The pH values appeared to be correlated with oxygen, with a correlation coefficient of +0.9465. Since pH is often determined by the amount of carbon dioxide in the water, the low pH and low O_2 values above Lake Livingston are probably related to the high BOD values in this region of the river.

Nitrogen values (NH_3, NO_2, NO_3) showed trends which are extremely characteristic of transitions in self-purification from a zone of recent pollution to a zone of recovery to a recovered zone. Ammonia shows a peak average value of 9.40 parts per million at Station 2. This level is maintained until Station 4 where the concentration begins to decline. NIPAK, Inc. Occasionally discharges significant amounts of ammonia in their effluent (McCullough, 1972) and may have affected the slight average increase at Station 4 compared with Station 3. A minimum average concentration of 0.41 parts per million is found at Station 9. Nitrite shows a maximum average value at Station 5 of 7.87 parts per million, and declines to a minimum average of 0.0008 parts per million at Station 9. Nitrate shows a maximum average of 2.66 parts per million at Station 6 and also decreases downstream to a minimum average of 0.16 parts per million at Station 10. This downstream trend of ammonia being replaced by nitrite, which is, in turn, replaced by nitrate, is a commonly observed phenomenon which occurs as a result of downstream oxidation of ammonia to nitrite to nitrate. It is also interesting to note that there is a net loss of nitrogen from above Lake Livingston. No immediate explanation can be made. Ammonia concentrations peaked at Station 4, nitrite peaked at Station 6, while the average phytoplankton biomass was found to peak at Station 4 and begins to decline downstream. The effect of the nitrogen peaks on phytoplankton biomass production is not clear. The decline may be due to grazing effects, increased turbidity and color, or to some other limiting nutrient.

Chlorides varied from 36 parts per million at Station 9 to 131 parts per million at Station 10. This tremendous increase at Station 10 is the result of salt water intrusion from Trinity Bay and salt water pollution from the Texas Gulf Sulfur Plant at this location. Tehaucana, Chambers and Richland Creek have been found to carry high concentrations of chlorides (McCullough, 1972). However, the results of this investigation do not show that the waters from these tributaries are having any significant effect on chloride concentrations at stations downstream from their confluence with the Trinity River. Station 5 only shows an average increase of 3 ppm above that at Station 4. Otherwise, above Lake Livingston, chlorides show a general decrease from Station 1 to Station 7.

Conductivity ranged from a high average of 790 micro mhos at Station 1 to a low average of 335 micro mhos at Station 9.

Sulfate concentrations ranged from a high average of 142 parts per million at Station 2 to a low average of 37 parts per million at Station 9. From Station 2 there was a general decline downstream with an increase at Stations 4 and 10 which are noteworthy. NIPAK has reported (Forrest and Cotton, 1970) 720 ppm of sulfate in effluents which may be responsible for the increase at Station 4. Station 10 increase may be caused by sulfate discharges from Texas Gulf Sulfur. McCullough (1972) reported 310 ppm sulfates in effluents from this plant. Sulfate was closely related to orthophosphate in the present study (r = +0.9246). The factors involved in this relationship are not known.

Turbidity varied from a maximum average of 161 JTU at Station 4 to a minimum average of 28 JTU at Station 9. Phytoplankton reached an average high at Station 4 which would contribute to turbidity. Color showed a maximum average of 117 color units at Station 7 and a minimum average of 55 color units at Station 9. Turbidity showed a significant decrease below Lake Livingston as a probable result of settling of suspended matter in Lake Livingston. Turbidity also showed a second high peak (other than the maximum at Station 4) at Stations 6 and 7. This increase may be the result of the inflow of turbid water from Chambers, Richland and Tehuacana Creeks. Color also increased at these stations. Color and turbidity probably limits primary productivity at Stations above Lake Livingston, particularly at Stations 4 through 7. FWPCA (1968) points out that color values in excess of 50 JTU will limit photosynthesis by phytoplankton.

Sediment oxygen demand S.O.D. was quite variable, but some general trends can be seen. Average values ranged from 32.4 parts per million of oxygen per kilogram dry weight of sediment per minute at Station 1 (with one value as high as 41.8 ppm) to a low of 7.4 ppm at Station 6. Generally, there was a decline in SOD downstream from the Dallas-Fort Worth area, thought to be the major source of the organics causing the demand. Station 7 was a major exception to this trend, and no immediate explanation can be given at this time for this result. Total organic carbon data from bottom sediments (Figure III-05 and Table III-01) reveals the same general conclusion as the Sediment Oxygen Demand (SOD) data. The bottom sediments from the Dallas-Fort Worth area (Stations 1 and 2) and the sediments below the confluence

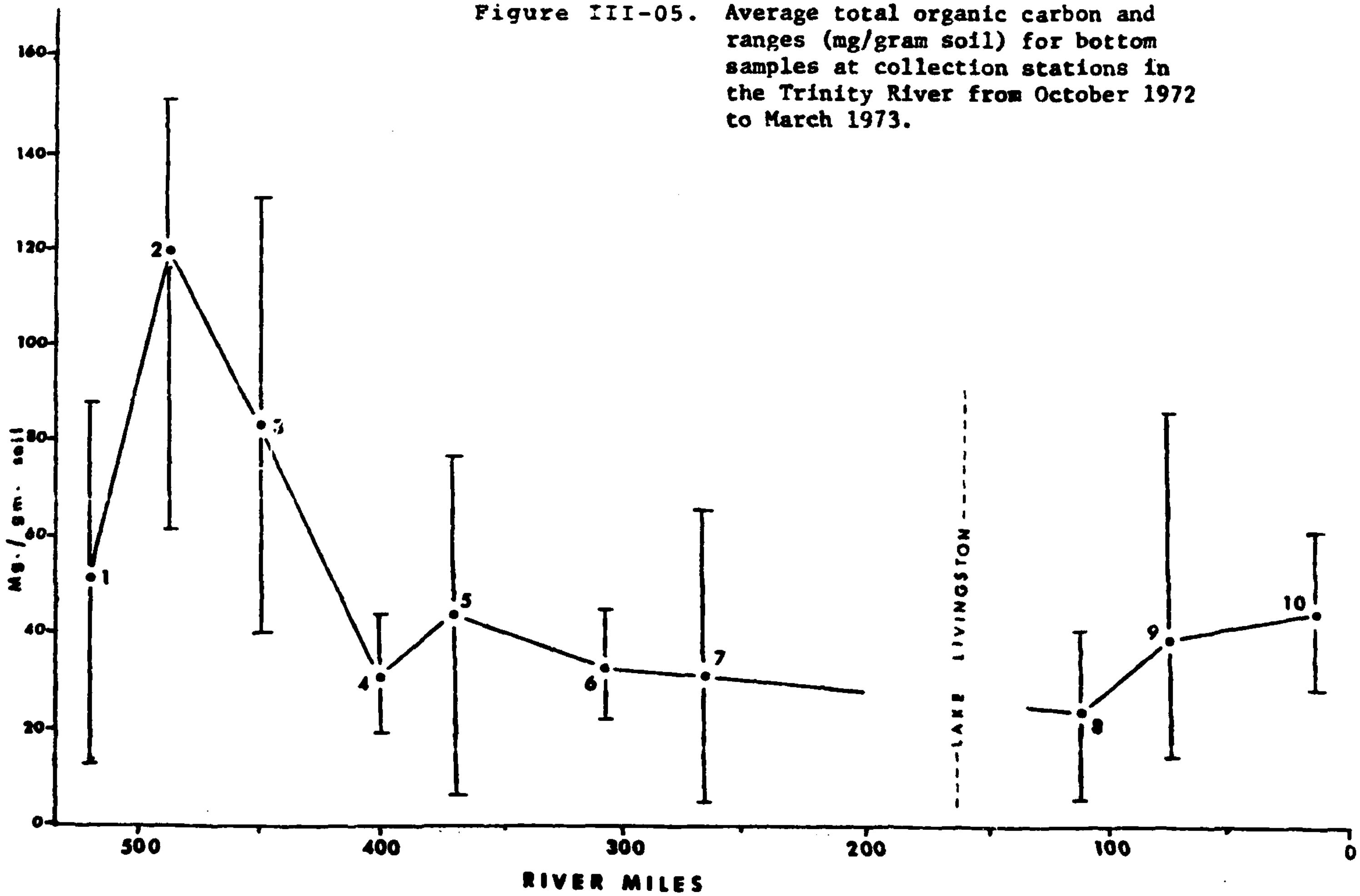


Figure III-05. Average total organic carbon and ranges (mg/gram soil) for bottom samples at collection stations in the Trinity River from October 1972 to March 1973.

Table III-01. Total organic carbon (mg carbon/ gram dry weight soil) for bottom samples from the Trinity River

Station 1		Station 2		Station 3		Station 4	
10-9-72	29.4	10-9-72	150.0	10-9-72	130.0	10-4-72	27.7
11-28-72	11.4	11-28-72	150.0	11-28-72	117.9	11-9-72	37.4
1-10-73	58.1	1-10-73	61.5	1-10-73	87.4	11-30-72	19.3
2-10-73	87.9	2-10-73	136.1	2-10-73	40.2	1-4-73	44.8
3-3-73	67.1	3-3-73	98.1	3-3-73	41.6	2-10-73	19.3
AVERAGE	50.8	AVERAGE	119.1	AVERAGE	83.4	3-3-73	42.4
						AVERAGE	31.8

Station 5		Station 6		Station 7		Station 8	
10-4-72	42.7	10-23-72	21.8	10-18-72	52.1	10-17-72	41.6
1-4-73	55.5	1-11-73	33.6	11-22-72	23.1	11-22-72	28.7
2-7-73	76.2	2-7-73	45.7	12-2-72	65.4	2-10-73	5.5
3-6-73	5.4	3-6-73	30.4	1-11-73	13.6	AVERAGE	25.3
AVERAGE	45.0	AVERAGE	32.9	2-7-73	4.9		
				3-6-73	36.1		
				AVERAGE	32.5		

Station 9		Station 10	
10-17-72	57.7	10-17-72	61.8
11-21-72	87.1	12-15-72	55.2
12-15-72	16.4	1-11-73	31.9
1-11-73	20.1	2-23-73	29.0
2-23-73	14.4	AVERAGE	44.5
AVERAGE	39.1		

of the Trinity River and the East Fork Trinity River, contain the highest amounts of total organic carbon. A thick layer of black sludge was very evident at Stations 1, 2, and 3 at most collecting periods, and appeared to be greatly reduced during periods of high flow. The origin of the organic sludge is primarily from sewage discharge, evidenced by the fact that the organic content of the bottom sediments progressively declined downstream from Station 2, the station nearest the greatest sewage discharge on the river. The total carbon data and sediment oxygen demand data strongly suggest that the sediments near Stations 1, 2, and 3 probably account for the depressed oxygen values observed during a river rise on the Trinity River. This oxygen depression was observed in water quality data collected during a river rise in this study and the phenomenon is reported to be the cause of frequent fish kills. The bottom sediments at Station 2, for example, with a very high oxygen demand and high organic content would be "scoured out" by flood conditions. The sediments at Station 2 did not ever appear to be dense or "tightly packed" on the bottom but were more loosely packed and easily disturbed by a strong current or an object such as the bottom sampler used to obtain sediments. As the sediments become resuspended, an enormous oxygen demand would suddenly be placed on the water mass, depressing the dissolved oxygen values.

On October 23, 1972 to October 31, 1972 water quality data was collected for Stations 5, 6, and 7 during a river rise. The results of chemical analysis on samples collected during these dates are given in Appendix III-02.

Although the data reflects only one river rise and only a segment of the river, only some generalities can be observed. Most of the stations showed a drop in dissolved oxygen as the river began to rise, followed by a general increase in dissolved oxygen. The turbidity, color and conductivity in most cases increased during the rise. At Station 5, the initial wave contained relatively high chloride and sulfate levels, perhaps as tributaries became flushed out upstream. Ammonia doubled its concentration as the initial flood waters arrived but three days later dropped to very low levels as the rise continued. Average BOD, POC and DOC were all relatively high during the water rise.

Particulate and Dissolved Organic Carbon

The results of dissolved organic carbon analysis (DOC) and particulate organic carbon analysis (POC) are given in Appendices III-01, III-02 and the average values for each

station in Figures III-06 and III-07. Average POC values ranged from 8.5 ppm at Station 2 to 3.2 ppm at Station 9, and average DOC values ranged from 8.5 at Station 2 to 4.7 at Station 8. A comparison is given in Table III-02 of the POC and DOC ranges in the Trinity River with other river studies.

Figure III-06 suggests that the principle source of particulate organic carbon, in the study area, is domestic sewage. The average POC value peaks at Station 2 and progressively declines at downstream stations. In this study, ammonia levels are indicative of recent sewage discharge. Simple linear regression shows ammonia values are highly correlated with POC values, with a correlation coefficient of +0.8229, significant at the 99% confidence level. It is of interest to note the wide range in values at Stations 4 and 5 which are the stations where phytoplankton biomass was usually quite dense. The general decline in POC downstream could be due to several causes. Much of the particulate matter introduced at Station 2 near Dallas could settle out downstream. The dilution effect, because of increased volume of the river, could also reduce POC values. Aquatic organisms (e.g. Bacteria, protozoa and filter feeders) could also effect a reduction in concentrations.

Brooks (1970) found in the Brazos River that POC was directly related to river discharge with the increased POC probably due to allochthonous matter being washed into the river during flooding conditions. Weber and Moore (1967) reported that POC was related to river height in the Little Miami River in Ohio. Both Brooks (1970) and Weber and Moore (1967) reported that DOC concentrations were not related to river discharge. In this study, no relationship between POC concentrations and discharge was observed. The Trinity River base flow is sewage, so that during low discharge the sewage is more concentrated and the POC would be high. During flood conditions the POC from sewage would be diluted but allochthonous detritus washed in by flood waters would increase the value, so that no clear relationship between POC and discharge could be expected. Brooks (1970) found DOC values to be the best indication of organic pollution. In this study both could be used as an indicator of water pollution since both showed an average maximum at Station 2 and generally declined downstream; however DOC was better correlated with BOD ($r = +0.70$) than was POC and BOD ($r = +0.51$). Simple linear regression showed DOC was correlated with orthophosphate ($r = +0.8295$)

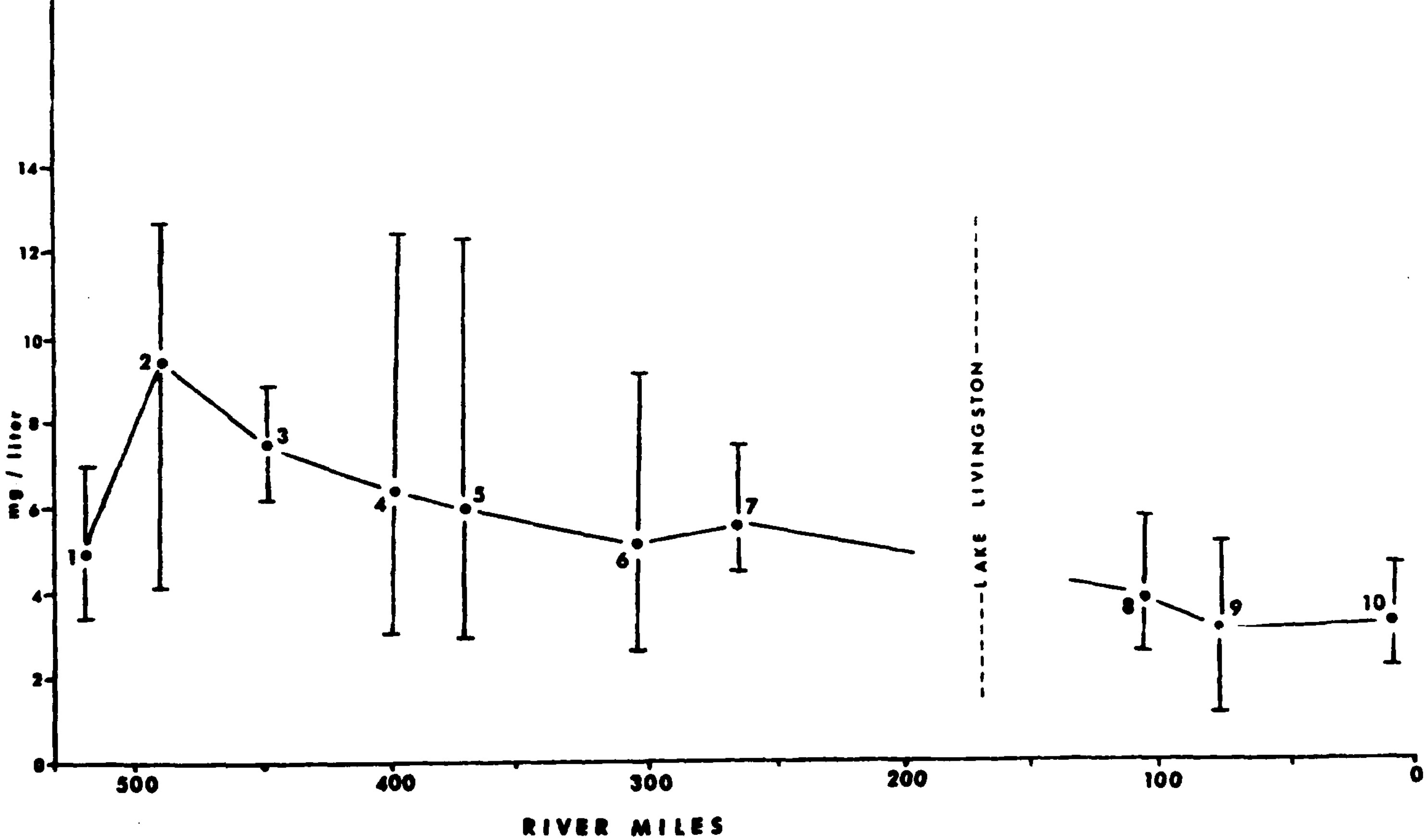


Figure III-06
Average Particulate Organic Carbon Concentrations and Ranges at Indicated Collection Stations in the Trinity River from September, 1972, through March, 1973.

Figure III-07
Average Dissolved Organic Carbon Concentrations and Ranges at Indicated Collection Stations in the Trinity River from September, 1972, through March, 1973.

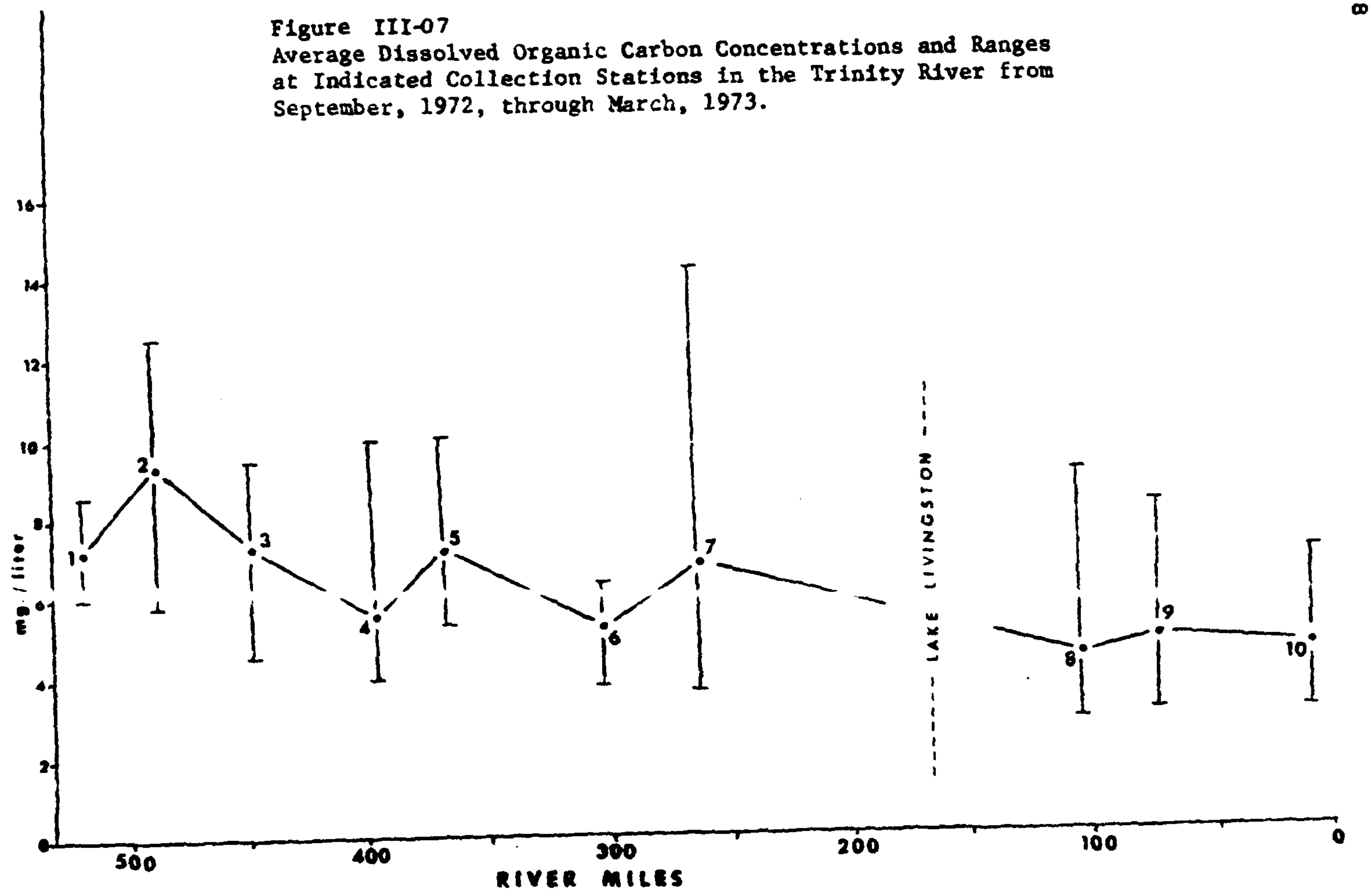


Table III-02. A comparison of DOC and POC ranges in the Trinity River and other rivers

River	Reference	DOC (ppm)	POC (ppm)
Trinity River, Texas	this study (1973)	2.9-14.1	1.1-13.6
Brazos River, Texas	Brooks (1970)	2.8-7.0	1.0-16
Guadalupe River, texas	Parker and Calder (1968)	1.0-5.0	1.0-5.0
Houston Ship Channel, Texas	Parker and Calder (1968)	1.4-26.0	2.2-20.0
Little Miami River, Ohio	Weber and Moore (1967)	2.5-12.5	---

significant at the 99% confidence level. Wilson (1963) found that the Colorado River in Texas increased in total organic carbon as it flowed to the coast.

Computation of Average Metric Tons/day (Avg/Mt/Day) for total Organic Carbon (DOC plus POC) indicates an increase in each constituent with river mile (Table III-03). The computation of Avg. MT/Day utilizes flow data to calculate an estimate of the mass balance transported by the river past the station sampled. Table III-03 compares the Avg/MTDay for TOC, DOC, and POC and calculates the River Index for organic carbon by dividing the Avg MT/Day by the total river mileage above the station for each station sampled. Station 3 below Dallas exports 9 times as much Avg MT/Day of TOC than Station 1 (between Fort Worth and Dallas) to 0.78 at Station 3 (below Dallas). High levels of organic carbon are transported to Station 8, where the TOC River Index drops back to 0.14. If Station 7 is considered the last high River Index (see Table III-03) and it is 315 miles downriver, the total river mileage polluted can be calculated as at least 255 river miles. This can be calculated by subtracting the 60 miles of river above Fort Worth-Dallas from the 315 miles. At least 1/2 of the entire Trinity River is affected by municipal or industrial sewage from the Fort Worth-Dallas area.

A calculated estimate of 3.52 x 10 Metric Tons/year of total organic carbon was exported by the Trinity River into Trinity Bay. This determination utilizes the data from Station 9 during the study period.

The following conclusions may be drawn from the organic carbon analysis:

1. The highest concentrations of DOC and POC were observed at Station 2 (near Dallas) with station means of DOC and POC being 8.56 ppm and 8.58 ppm respectively.

2. The largest Average Metric Tons per Day of TOC, DOC, and POC were observed at Station 3, located just below the confluence of the Trinity River with the East Fork of the Trinity River.

3. On the average, at least 250 miles of the Trinity River (or 1/2 of the river mileage) is affected by the municipal and industrial sewage wastes from the Fort Worth-Dallas area.

Table III-03. Index of average metric tons/day/river mile of total (TOC) dissolved (DOC) and particulate (POC) organic carbon to each station of the Trinity River, Texas

Station	River Miles Above Station	Avg. TOC MT/Day	Index	Avg. DOC MT/Day	Index	Avg.POC MT/Day	Index
1	60	11.89	0.20	6.75	0.11	5.14	0.09
2	90	43.07	0.48	20.89	0.23	22.18	0.25
3	125	97.27	0.78	44.14	0.35	53.13	0.42
4	180	70.51	0.39	28.70	0.16	41.81	0.23
5	210	69.03	0.33	41.51	0.20	27.51	0.13
6	270	80.15	0.30	31.00	0.12	49.19	0.18
7	315	90.94	0.29	38.52	0.12	52.42	0.17
8	465	66.96	0.14	41.40	0.09	25.56	0.06
9	500	96.31	0.19	62.92	0.13	33.54	0.07
Means		69.57	0.34	35.09	0.17	34.50	0.18

4. A calculated estimate of 3.52 x 10 Metric Tons per year of Total Organic Carbon was exported by the Trinity River into Trinity Bay, utilizing the data collected from Station 9 during the study period.

Pesticide Analysis

Collection and subsequent analysis of river sediments was made during 1972-73, as previously described in the methods section. A total of 49 samples were collected. Results of these analyses are given in Appendix III-03 and Table III-04. Out of 49 samples, 45 contained measurable amounts of Chlordane (92.0%), and 38 samples contained measurable amounts of DDE (77.5%). Measurable amounts of Heptachlor were found in 20 samples (40.8%). Lindane was found in 12 samples (24.5%), DDT in 8 samples (16.3%), and Aldrin in 6 samples (12.3%).

Dieldrin and Endrin were found in 4 and 5 samples, respectively, Mirex in 2, and Methoxychlor was not detected in any samples. Table III-05 gives the means and standard deviations for pesticides in micrograms per kilogram of sediments for the entire river.

Chlordane varied between 402.47 mcg/kg at the Rosser station on October 12, 1972 to 0.00 mcg/kg at the Cayuga station on January 12, 1973. DDE showed a smaller range. It varied between 10.99 mcg/kg sediment at the Rosser station on January 12, 1973, to undetectable amounts on several occasions. Analysis of variance indicates that both DDE and Heptachlor are statistically related to Chlordane concentration (α=.01). Heptachlor, itself was detected more often in the upper three stations than in the lower three. It occurred in 75.3% of the samples collected in the lower three. Concentrations of Lindane were relatively low at the Highway 7 and 21 stations with a high of just over one microgram per kilogram sediment. Lindane concentrations were detected in 5 out of 19 samples at the Fairfield and Cayuga stations and ranged between 0.93 mcg-kg to 3.92 mcg/kg sediment. Sediments from the uppermost stations, Highway 85 and Rosser, showed the highest concentrations of Lindane. It occurred in 5 out of the 13 samples and ranged between 1.05 to 6.52 mcg/kg.

Aldrin was shown to be concentrated around the Cayuga station. When present it ranged between 0.62 to 9.58 mcg/kg

Table III-04. Pesticide quantities for the year 1972

Averages (mg/kg)

	Rosser	HiWay 85	Cayuga	Fairfield	HiWay 7	HiWay 21
LINDANE	1.60	0.44	.64	.40	.28	<.05
ALDRIN	.62	0.00	1.31	<.04	0.00	<.02
CHLORDANE	127.02	49.69	22.41	12.09	9.75	25.15
HEPTACHLOR	5.07	.80	.56	<.14	.05	<.13
P P' DDE	3.85	2.36	1.10	.50	.65	.91
p P' DDT	0.00	0.00	.88	.12	.67	.53
MIREX	0.00	0.00	.17	0.00	.18	0.00
ENDRIN	1.89	0.00	.45	0.00	0.00	.69
DIELDRIN	0.40	0.42	.61	0.00	0.00	0.00
METHOXYCHLOR	0.00	0.00	0.00	0.00	0.00	0.00

STANDARD DEVIATIONS

	Rosser	HiWay 85	Cayuga	Fairfield	HiWay 7	HiWay 21
LINDANE	2.69	0.98	1.30	.97	.35	.09
ALDRIN	1.76	0.00	3.15	.007	0.00	.07
CHLORDANE	131.51	65.32	28.20	10.80	11.38	35.93
HEPTACHLOR	10.09	0.83	.77	.18	.12	.22
P P' DDE	3.96	3.81	1.51	.37	.73	.77
P P' DDT	0.00	0.00	2.43	.37	1.18	1.03
Mirex	0.00	0.00	.51	0.00	.48	0.00
ENDRIN	5.35	0.00	1.34	0.00	0.00	1.28
DIELDRIN	1.13	0.95	1.28	0.00	0.00	0.00
METHOXYCHLOR	0.00	0.00	0.00	0.00	0.00	0.00

Table III-05. Mean concentrations of pesticide for the upper Trinity River for 1-1-1972 through 1-12-1973

Pesticide	Mean Concentration	Standard Deviation
Chlordane	41.01	44.40
DDE*	1.56	1.30
Heptachlor	1.12	1.95
Endrin	0.50	0.73
Lindane	0.56	0.54
DDT*	0.37	0.37
Aldrin	0.33	0.53
Dieldrin	0.23	0.27
Mirex	0.06	0.09
Methoxychlor	0.00	0.00

*Reported as pp' isomers only.

and was found in 3 out of 9 samples taken from that station. Aldrin was not detected at the Highway 85 station and was detected only once at the Rosser station. Samples taken from below the Cayuga station showed only traces of Aldrin residues.

Endrin residues were detected once at the Rosser station, once at the Highway 85 station, and once at the Cayuga station. It was found twice at the Highway 21 station. No detectable quantities were found at the Fairfield and Highway 7 stations. DDT was not found at the two uppermost stations, Rosser and Highway 85, but was found in two samples from the Cayuga station. It appeared more often at the two lowermost stations, being found in 5 out of 14 samples. Detectable amounts of DDT ranged between 0.22 to 7.34 mcg/kg sediment. It was found once at the Fairfield station.

Dieldrin was not detected at the three lowermost stations. The three uppermost stations had four samples with detectable quantities of Dieldrin residues. Mirex was found in only two samples: one from the Cayuga station and the other from the Highway 7 station. Methoxychlor was not found in any samples taken.

Statistical treatment of the data indicates that there is no significant difference in the mean concentrations of any two adjacent stations for the following items: Chlordane, DDE, Heptachlor, organics, clays, silt, or sand. An unpaired t-test was used to determine this factor and the level of significance ($\alpha=0.05$). This test is very sensitive to the sample variances. A Mann-Witney non-parametric rank test confirms that the differences between adjacent stations is not significant ($\alpha=0.05$). Student's t-test indicate that there is a significance difference between the Rosser station and the lower stations with the exception of the station at Highway 82 which is adjacent to it.

Multiple quadratic regression analysis indicate that there is a high correlation between Chlordane and percent organics, and DDE and percent organics ($\alpha=0.01$). Regression analysis also indicates a strong relationship between the above mentioned pesticides and percent clays ($\alpha=.01$). Regression analysis, on the other hand, shows silts to be a poor predictor of Chlordane and DDE concentrations. Data suggest an inverse relationship between percent sand and Chlordane and DDE.

Pesticide concentrations in the bottom sediments below Lake Livingston appear to be quite low. One sample collected near Wallisville, Texas near the bridge on Interstate Highway 10, contained only two insecticides, Lindane (0.2 micrograms per kilogram of sediment) and Chlordane (less than 1.0 microgram per kilogram of sediment). It would appear that the rice production adjacent to the lower Trinity River is not resulting in significant pesticide contamination of the sediments.

Pesticide analysis of well water samples collected near Rosser, Texas did not produce any dectable quantities of pesticides.

Monitoring pesticides at the residue level has become an essential parameter in assessing the fitness of a lotic environment (Barthel et. Al., 1969; Breidenbach, et al., 1967; Brown and Nishioka, 1967). The action and effect of pesticides on non-target organisms have emphasized the need for monitoring the levels of insecticides introduced into the freshwater ecosystem. Since the early fifties, scientists have recognized that chlorinated pesticides do accumulate in the environment and can have adverse effects on aquatic biota (Surber, 1948; Sun, 1950; Young and Nicholson, 1951).

Pesticides may enter the fresh water environment through a number of routes. Drift from aerial application of agricultural crops, accidental direct application of an adjacent stream (Ide, 1957), and direct application for aquatic pest control (Weidhass, Shhmidt, and Bowman, 1960) may occur. Nicholson (1967), however, believes that a large percentage of pesticide contamination comes from industrial waste discharge from such industries as pesticide manufacturers and formulators, and from surface runoff and erosion. Since degradation of many of the organochlorine pesticides are slow, one could expect a sustained burden of residues in rivers that are adjacent to large agricultural regions. Fortunately, pesticide runoff is greatly retarded by the insecticides' affinity for soil particles (Grzenda et al., 1964; Young and Nicholson, 1951).

The pesticide concentrations in river sediments is dependent on the watershed associated with a particular river. Land use patterns, surface erodability, and rainfall influence the extent of residue burden a river will have. Soil composition of the surrounding treated acreage appears to determine the rate of movement from rain runoff. Bailey and White (1964) have shown that pesticide runoff is

significantly decreased by the percentage of organics in the soil. They have also shown that soil texture influences the movement of pesticides, with soil particles of smaller size having the greater affinity.

Once the pesticide has entered the river environment, its fate is again partly dependent on the type of sediment with which it has become associated. Finer textured sediments would have a proportionately greater concentration of pesticides and would be more easily transported downstream (Bailey and White, 1964; Wharton, 1970). Since most of the chlorinated pesticides are fairly hydrophobic, the majority of the residue found in water is found on suspended particles and not dissolved in the water itself (Crocker and Wilson, 1965). As the river kinetics decrease, the decreased load capacity allows the pesticide containing sediments to settle out. It is not unusual to find that the pesticide contents in silt and clay deposits of a slow moving river exceed that of the water by several hundred fold (Edwards, 1970).

Percent organics, sand, silt, and clay were determined in order to assess what relationship exists in the Trinity River between soil composition and pesticide contents. Several generalizations may be drawn from the data. According to statistical treatment of the data collected, there is a significant quadratic relationship between Chlordane and DDE residues and that of organic and clay content in sediments. These pesticides do not appear to be well correlated with silts; however, sand is negatively correlated with pesticide content. The occurrence of other pesticides were so scant that statistical treatment was difficult. The averages of percent organics, clays and silts generally decrease downstream as do pesticide concentrations. Pesticide concentrations increase slightly on the Highway 7 and Highway 21 stations yet, percent organics, silt and clays do not. The pesticide content appears to be dependent on other factors such as rainfall, discharge, season and agricultural land use, as well as chemical and physical parameters of the river itself.

Second order regression analysis of the data in this study indicates that percent organics or percent clays are good predictors for Chlordane and DDE levels in sediments. The following table gives correlation coefficients for the above mentioned pesticides and the percentage of general

sediment type from which they came:

	r-values
Chlordane vs. Percent organics	.951**
DDE vs. Percent organics	.994**
Chlordane vs. Percent clays	.947**
DDE vs. Percent clays	.987**
Chlordane vs. Percent silt	.652 N.S.
DDE vs. Percent silt	.686 N.S.
Chlordane vs. Percent sand	.912*
DDE vs. Percent sand	.895*

* indicates significance at the 95% confidence level.
** indicates significance at the 99% confidence level.
N.S. Indicates no significance.

The data suggest a strong relationship between organics and DDE , and organics and Chlordane. Clays also show positive correlation for these pesticides, but silts do not. Sand content appears to be correlated, also, although the data suggests that its effects on Chlordane and DDE are opposite from that of clays and organics.

These data appear to agree with Bailey and White (1964, 1969) findings that pesticides have increasing affinities for sediment particles of smaller and lighter texture. They suggest three factors in which these particles may interact: (1) adsorption by Coulombic forces, (2) physical adsorption through dipole interaction (primarily Van der Waal forces), (3) and by adsorption through hydrogen bonding. Kunze (1966) suggests that "...chlorinated hydrocarbons tend to associate or accumulate in the organic fraction [and that this] may be due to compounds in the organic matter which act as solvents for these insecticides."

The source of pesticide contamination is not definitely known. Data from the Texas A & M Extension Service indicates that the counties adjacent to the Rosser station utilize more insecticides than the lower counties. The data presented in this report suggest that the river recovers from this pesticide burden as it proceeds downstream. Bailey and Hannum (1965) reported a decrease of pesticide residues in river water of a rate of 0.0016 micrograms per liter per mile downstream from the application point. LeGrand (1966) states that:

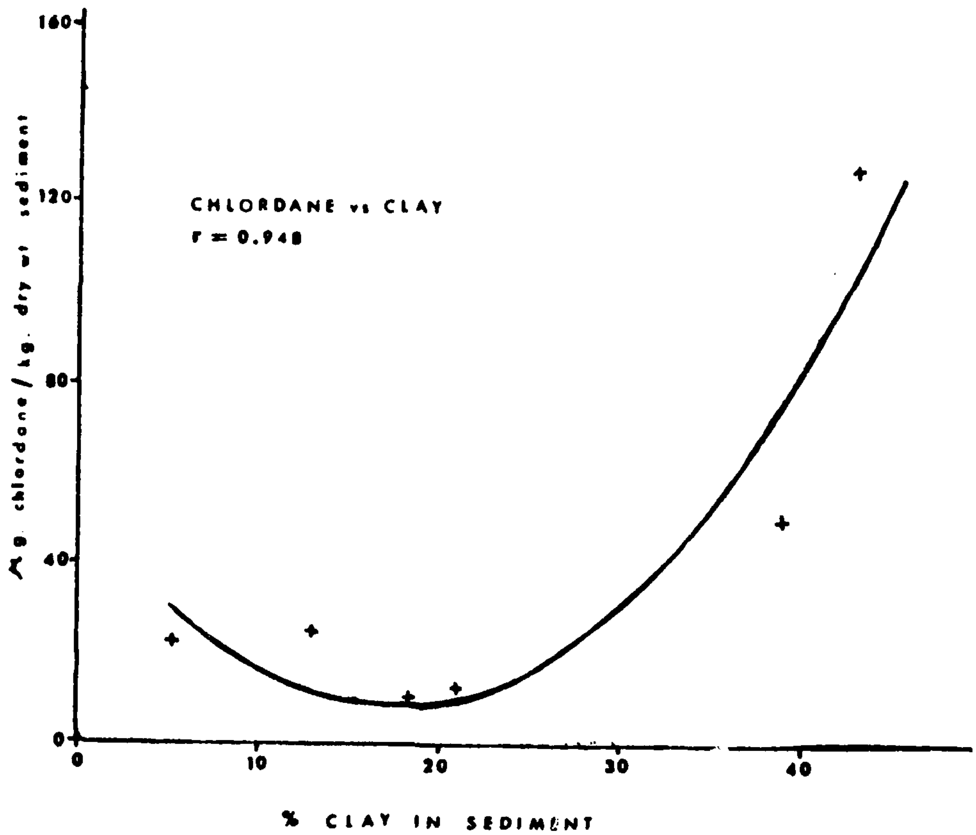
> "When waste containing pesticides comes in contact with water or the soil, contaminates in them start to move with the entraining water, and they also start a complex course of attenuation, or weakening in strength and consistency...by decay or some inherent power to decrease in potency, by sorption or soil materials, and by dilution through dispersion."

The upper Trinity is subject to large amounts of domestic sewage from urban areas in the Dallas-Fort Worth area (McCullough, 1972). The organic matter associated with this region of the river has shown to exert its influence in at least the upper three stations covered in this study (McCullough, 1972). Some of the pesticide residues recovered may have come from domestic and industrial discharge. These residues could easily be transported by organic matter for which pesticides have a great affinity (Bailey and White, 1969).

The quadratic relationship of Chlordane and DDE with that of organics, clays, and sand may be due to factors other than the pesticide-sediment interaction. The proximity of the station to agricultural usage may be of importance in evaluating to what extent the pesticides and sediments will interact. The Fairfield, Highway 7 and Highway 21 stations, for instance, receive waters from tributaries that drain agricultural areas (McCullough, 1972). These tributaries (i.e., Chambers, Richland, and Tehuacana creeks) are also characteristically low in organics (McCullough, 1972). Chambers Creek drains much of Ellis County. County extension agents report that some 414,000 acres in Ellis County have been treated with insecticides in 1971 (McCullough, 1972). All three creeks drain Navarro County. In 1970, Navarro County was reported to have treated 49,100 acres with insecticides (McCullough, 1972).

The three points of the regression line (see Fig. III-08), that cause it to bend upward for lower clay and organic containing sediments represent Fairfield, Highway 7, and Highway 21 stations. The increased average pesticide concentrations at those stations may be due to Chambers, Richland, and Tehuacana creeks which form a confluence with the Trinity River a few miles upstream.

Figure III-08. Second order regression analysis, $y = b(0) + b(1)x + b(2)x^2$, of pesticide concentrations vs. clay and organics in the Trinity River, Texas, from January, 1972, to January, 1973.



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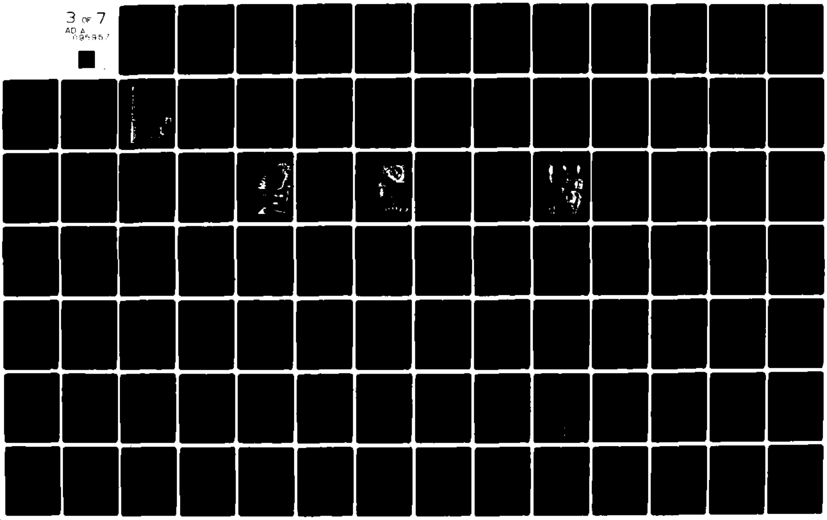


Figure III-08 (cont.)

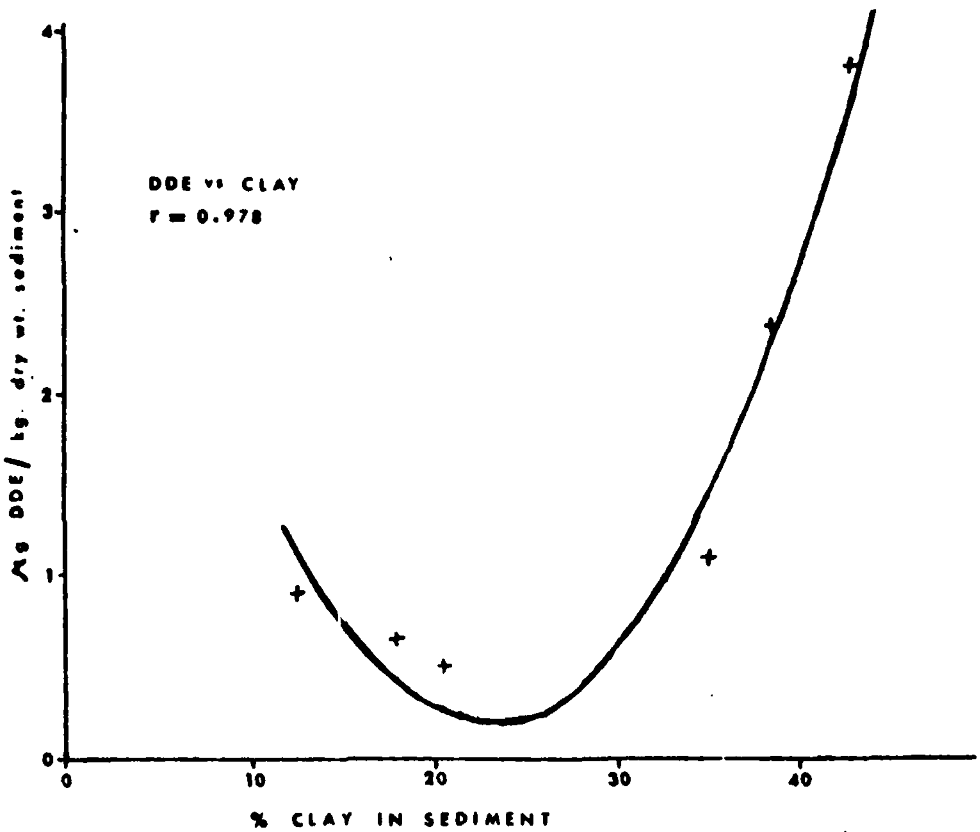
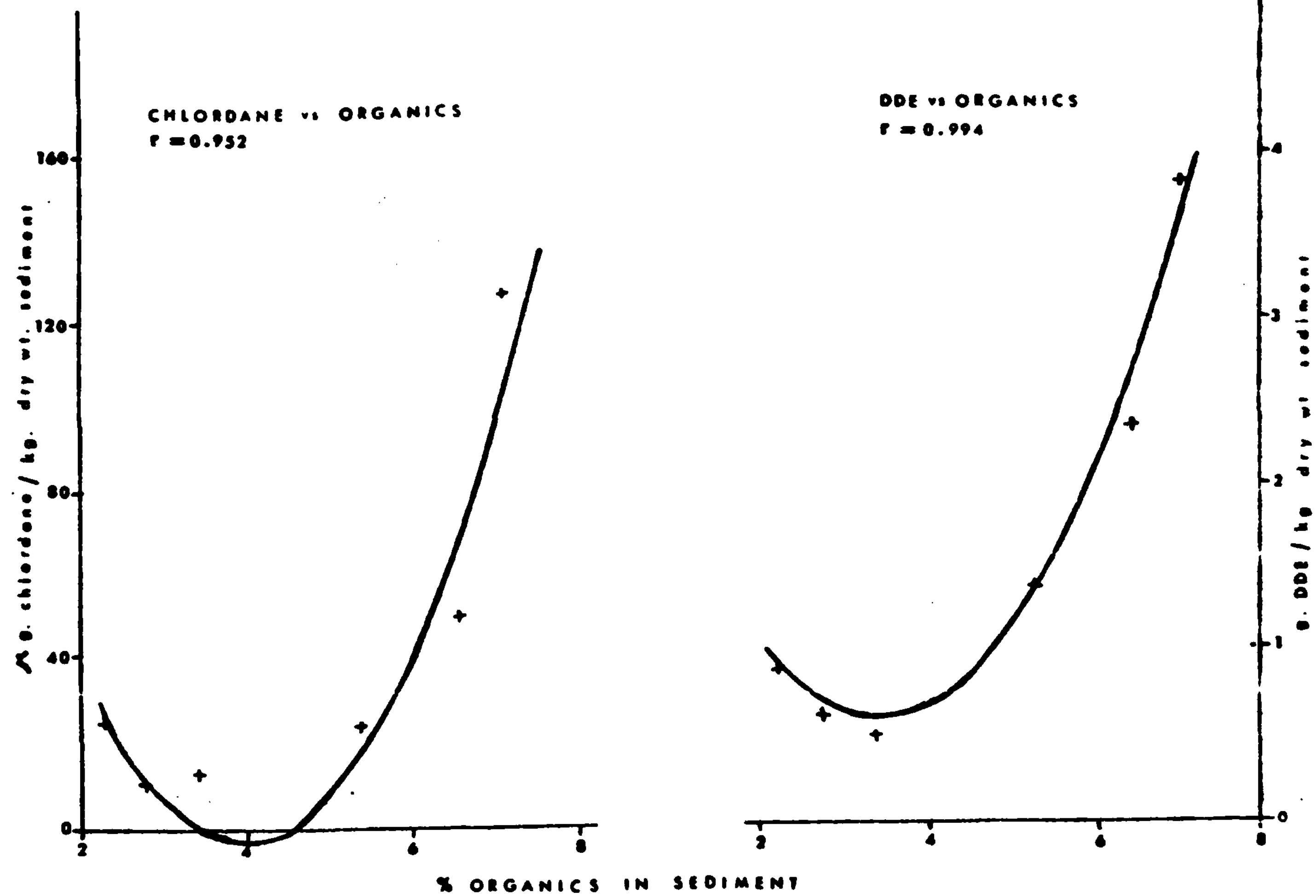


Figure III-08 (cont.)



In an environment as dynamic as a river, explaining relationships between parameters can be very complex. Sediment composition is just one of the many factors invluencing the amount of pesticides that will be recovered on any given day and sample. Experimental technique may also enter into the problem, since some sediment types give greater pesticide recoveries than others (Bailey and White, 1964).

Pesticide usage information, when compared to residues, suggest that most of the pesticides entering the river come from agricultural application (Fig. III-09 and Table III-06). Much of the clays associated with the uppper Trinity River originate from land that is either agricultural in nature or which is adjacent to such areas. Since clays are easily suspended in water, it could be transported downstream and redeposited. If pesticides originate from this area, it would not be surprising to find that clays and pesticides are closely related to one another. Regression analysis of the data presented bears out this finding. Unfortunately, clay and organics are significantly correlated (r=.88) also. This is understandable since organics have a great affinity for clay particles (LeGrand, 1966). A more structured study would have to be done in order to determine whether the residues become associated first with the organic matter and then the clays or with the clays first and then the organics.

Figure III-09 illustrates the relationship between DDE, Chlordane, and pesticide usage with that of river miles upstream. The figure indicates that there is a trend for these residues to decrease rapidly downstream, then to level off, and finally, increase slightly. Pesticide usage in adjacent counties follow the same pattern.

Northern reaches of the Trinity River basin are characterized by large agricultural land use. Cotton, sorghum, grains, and forage crops are abundant in Ellis, Kaufman, Navarro, and Anderson counties (McCullough, 1972).

Peanuts, vegetables, soybeans and oats are among the principle crops in more central river basin counties such as Houston and Leon counties (McCullough, 1972). Estimates of pesticide usage appear to be greatest in the more northern counties with a marked decrease downstream (McCullough, 1972). This decrease may be due not only to less agricultural acreage, but to production of crops requiring lower pesticide application as well.

Figure III-09
Relationship of op'DDE and Chlordane Concentration in Sediments with Cumulative Acres Treated with Pesticides in Counties Adjacent to the Trinity River from January 1972 to January 1973

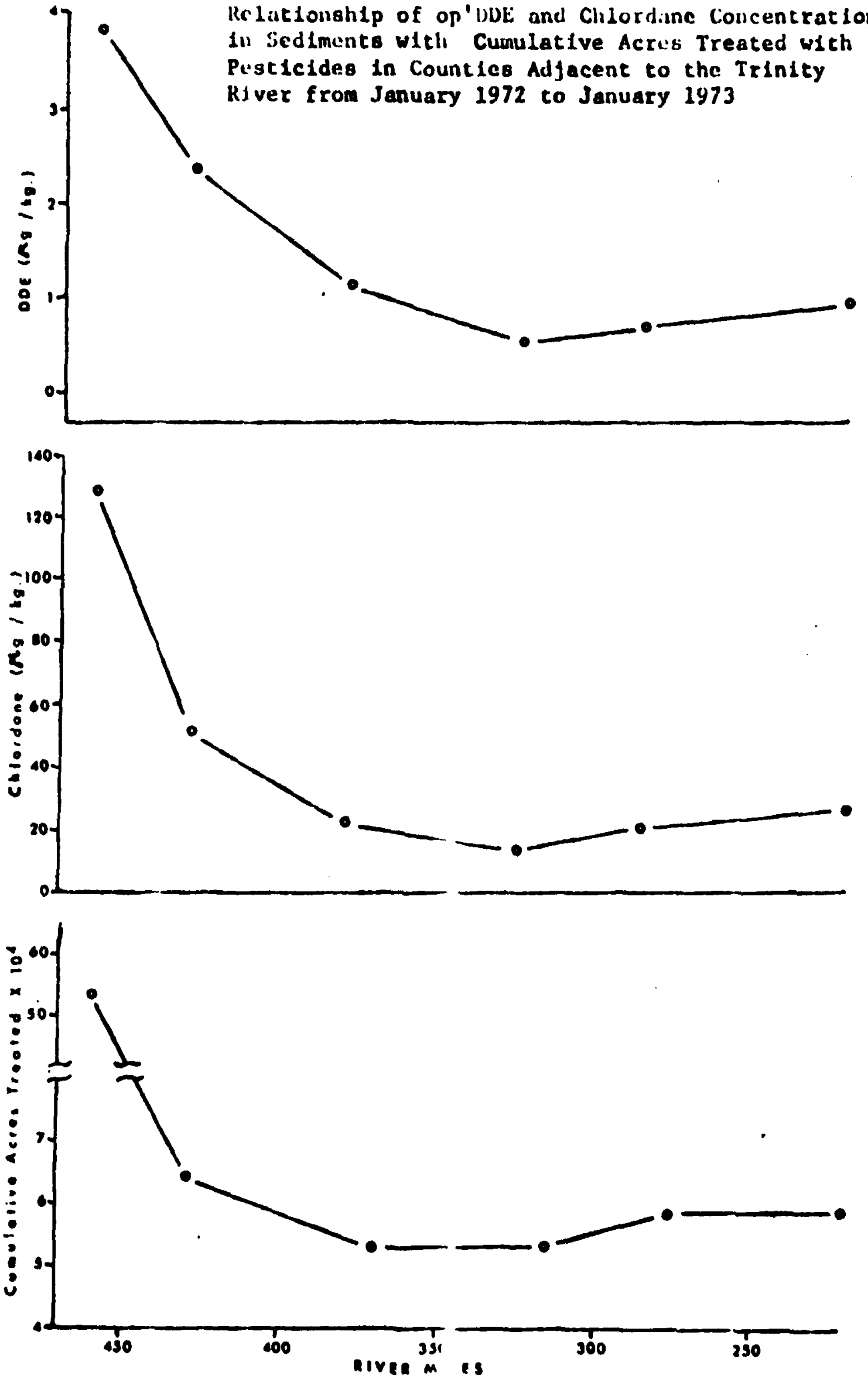


Table III-06. Cumulative acreage treated with insecticides in 1970-71.

STATION NAME	COUNTY ADJACENT TO STATION	CUMULATIVE ACREAGE TREATED
Rosser	Ellis	414,000
	Kaufman	119,000
Highway 85	Henderson	14,900
	Navarro	43,100
Cayuga	Anderson	43,427
	Freestone	9,000
Fairfield	Anderson	43,427
	Freestone	9,000
Highway 7	Leon	10,000
	Houston	48,000
Highway 21	Leon	10,000
	Houston	48,000

Data supplied by the Texas A. & M. Extension Service, Texas A. & M., College Station, Texas.

Pesticide residue averages appear to be well correlated with application (see Figure III-09). The greatest concentrations of pesticides were found in sample sites closest to Dallas. Residues were found less frequently and less abundantly downstream with a slight increase at sites adjacent to Leon and Houston counties. This increase is not of statistical significance, due to the high variances encountered at these two stations.

The most frequent pesticide encountered was Chlordane, which was found present in 96% of the samples tested. DDE was found in 79% of the samples and Heptachlor in 55%. DDT and Lindane occurred in 17% and 36% of the samples analyzed, respectively. Aldrin, Endrin, and Dieldrin occurred less frequently. Mirex was found in only two samples, and methoxychlor residues were not found.

The scarcity of DDT upstream coupled with the frequency of occurrence of its metabolite, DDE, suggest a decrease in its usage (Tidswell and McCasland, 1972). It is interesting to note that although Rosser and Highway 85 stations showed the greatest concentrations of DDE, no DDT residues were identified. Tidswell and McCasland (1972) found no DDT for stations on the West Fork of the Trinity at Loop 12 East and Loop 12 West and at Arlington on State Highway 360, yet they found frequent occurrence of DDE. At stations on the West fork at Fort Worth and the Clearfork at Fort Worth, Tidwell and McCasland had similar results.

Guenzi and Beard (1967) have shown that DDT is dechlorinated rapidly in an anaerobic condition, by bacteria such as _Escherichia coli, Enterobacter_ (reported as _Aerobacter_), and _Proteus._ Hill and McCarty (1967) report similar results. The Trinity River frequently contains dissolved oxygen of less than 3 ppm in these areas and has been known to contain high concentrations of bacteria similar to those used in the Guenzi and Beard experiments (Harris, Mary Anne J., unpublished thesis, Stephen F. Austin State University, Nacogdoches, Texas).

Of the mixture of pesticides sampled, Chlordane appears to predominate. The concentrations of Chlordane are not only highest at the Rosser station, but also the most variable. The highest concentration of Chlordane at the Rosser station was 402.47 mcg/kg and the lowest concentration was 9.67 mcg/kg the average concentration was 127.02 mcg/kg sediments and the standard deviation was 131.51. It appears that during 1972, the highest pesticide concentrations are in the fall and the lowest are in late

spring and early summer. Unfortunately, no data was taken for the months of July and August.

Heptachlor was found in 55% of the samples taken. Its occurrence is possibly due to Chlordane being present, since Chlordane has as one of its constituents Heptachlor. Regression analysis show that the two pesticides are correlated at the 99% confidence level (r=0.85). The mode of entry into the aquatic environment may be similar for the two pesticides. This latter possibility is very plausible when one considers that the concentration of Chlordane and DDE are also correlated (r=0.96, =0.05).

Three out of eight samples at Rosser contained Lindane, and one of the eight samples contained Endrin, Dieldrin, and Aldrin. These pesticides were all encountered on November 28, 1972. Collections at other stations show a wide variety of pesticides during this period.

The Cayuga station showed the highest concentration of DDT encountered (7.34 mcg/kg) during November, 1972, along with Aldrin and Dieldrin residues. The concentration of Chlordane and DDE decreases rapidly as one proceeds downstream, withe the Highway 85 station showing a marked decrease in the residues followed by a more gradual decrease and finally by a slight increase. The reasons for this are only speculative. It appears that agricultural use plays a significant role as Figure III-09 would indicate. Pesticide residues carried downstream most likely play some part. Pesticides have a very high affinity for soil particles (Bailey and White, 1969; Nicholson, 1969), and Breidenbach and Lichtenberg (1963) suggest that rivers may effectively remove pesticides by siltation. Nicholson (1967) found .33 ppm DDT in stream water thirty minutes after the watershed had been sprayed, but twenty-seven hours later no pesticide could be detected. During greater river discharge, the pesticide-containing silt and clays could be carried downstream and then redeposited.

A very interesting relationship appears to exist between rainfall and DDE concentrations. Figure III-10 shows the average monthly rainfall in the region studied as compared to average DDE concentration for each month. It appears that during months of high rainfall and therefore, increased discharge, the DDE laden sediments are scoured out. During periods of decreased discharge, these sediments along with newly introduced sediments could be redeposited. This could account for the increased in DDE during periods of lower rainfall. It is realized that this is only

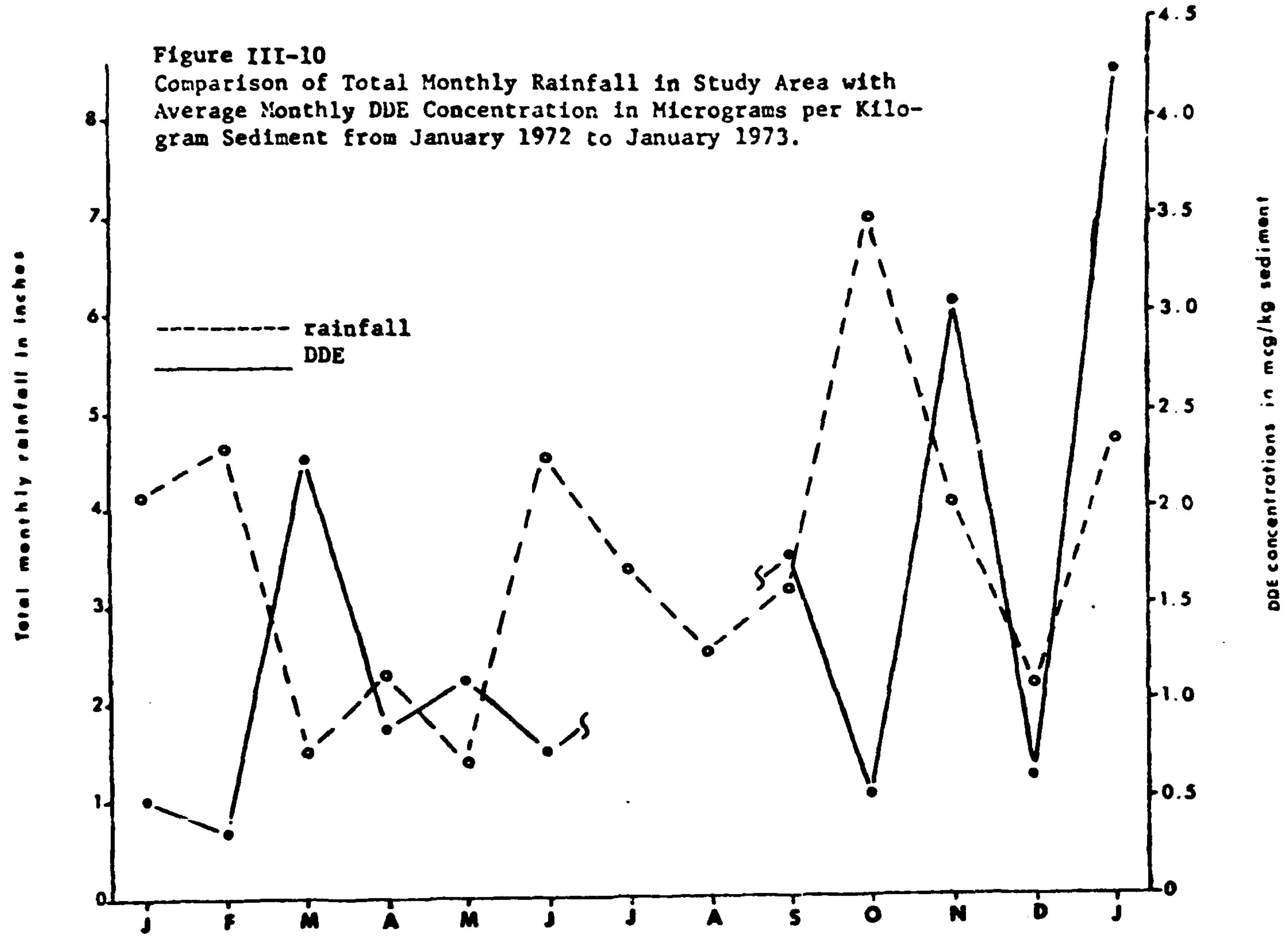


Figure III-10
Comparison of Total Monthly Rainfall in Study Area with Average Monthly DDE Concentration in Micrograms per Kilogram Sediment from January 1972 to January 1973.

indirect evidence that such a relationship does exist. Tidwell and McCasland (1972) in their study of the Trinity River and other Texas rivers warn that "...many variables exist in the relationship....Additional variables would include the quality of the sample, the availability of the deposited sediment, the time difference between deposition and collection, and many other." A misinterpretation does exist in most cases in a graph such as this one. Part of this is due to the way the graphs were made. First, the pesticide average concentrations were placed in the center of the month rather than relative to the actual time of the month they were taken. Second, the graph represents the total average rainfall for the entire month. These data were derived by taking ten representative rainfall stations along the river and taking their average.

Regardless of these faults, the data appear to follow the particular pattern previously described although an abnormality exists in the January, 1973 samples. This anomaly can be improved when one examines the precipitation patterns of the month more closely. Most of the precipitation occurred in the first and last week of the month while the sample was collected on the twelfth. Crockett reported over three inches of precipitation in the first week of January. This date marked the beginning of rainfall lull that lasted nearly a week. This may account for the unusually high DDE concentrations found although what relationship, if any is only speculative.

<u>Phytoplankton and Periphyton</u>

The results of phytoplankton biomass and phytoplankton chlorophyll analysis are given in Figures III-11 and III-12 and Appendicies III-04 and III-05. In general, chlorophyll analyses is correlated with phytoplankton biomass, with chlorophyll <u>a</u> concentrations appearing to better correlated with phytoplankton than the total of chlorophyll <u>a, b, and c.</u> The phytoplankton biomass ranged from a low of 6.1×10^5 cells per liter at Station 1 to a high of 63.3×10^5 cells at Station 3. A phytoplankton "bloom" is generally defined as 10^6 algal cells per liter.

The data indicate average phytoplankton density increases progressively from Station 1 downstream, reaching a peak in average biomass at Station 4. The population declines from Station 4 downstream to Station 8, and then begins to increase again at Stations 9 and 10.

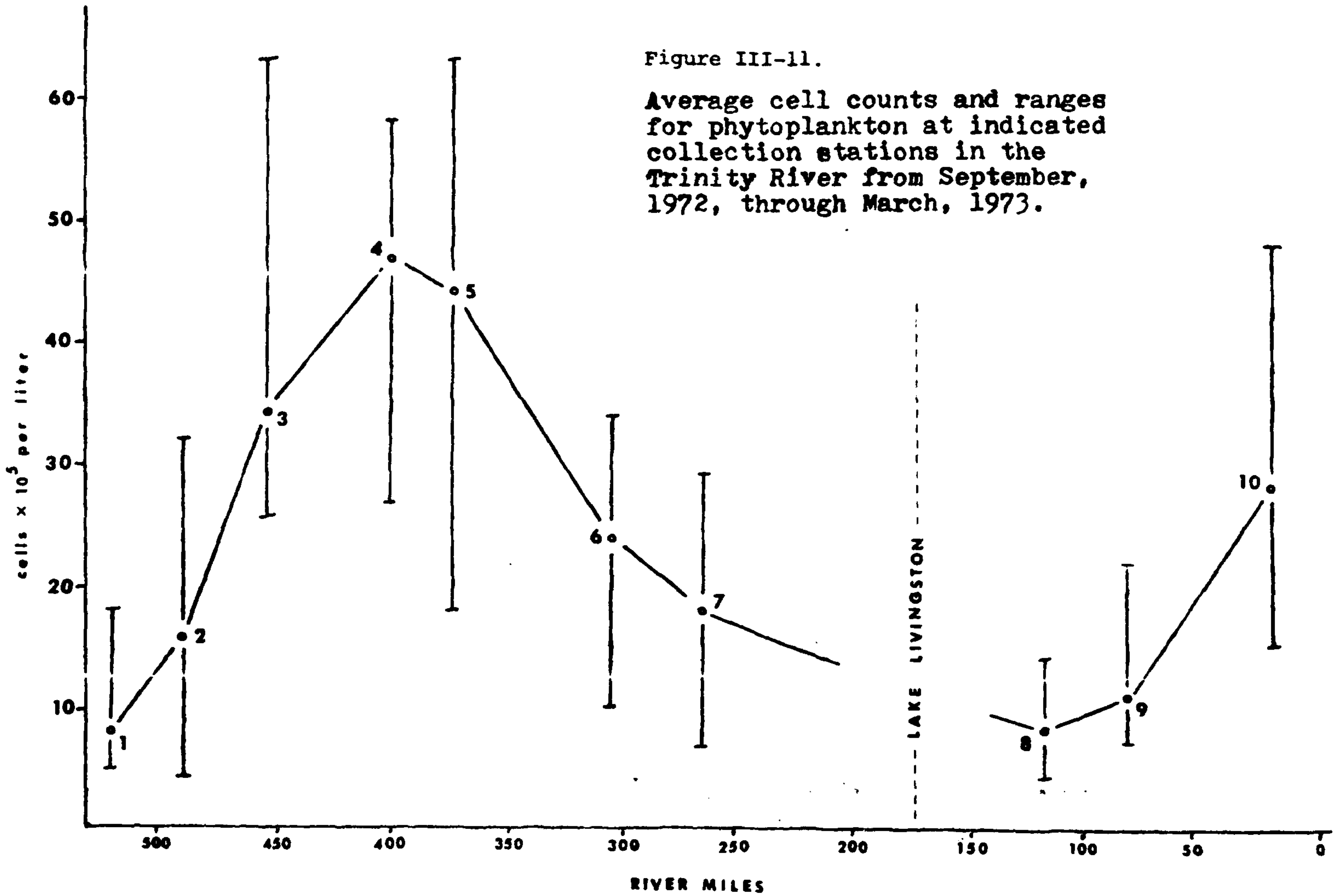


Figure III-11.

Average cell counts and ranges for phytoplankton at indicated collection stations in the Trinity River from September, 1972, through March, 1973.

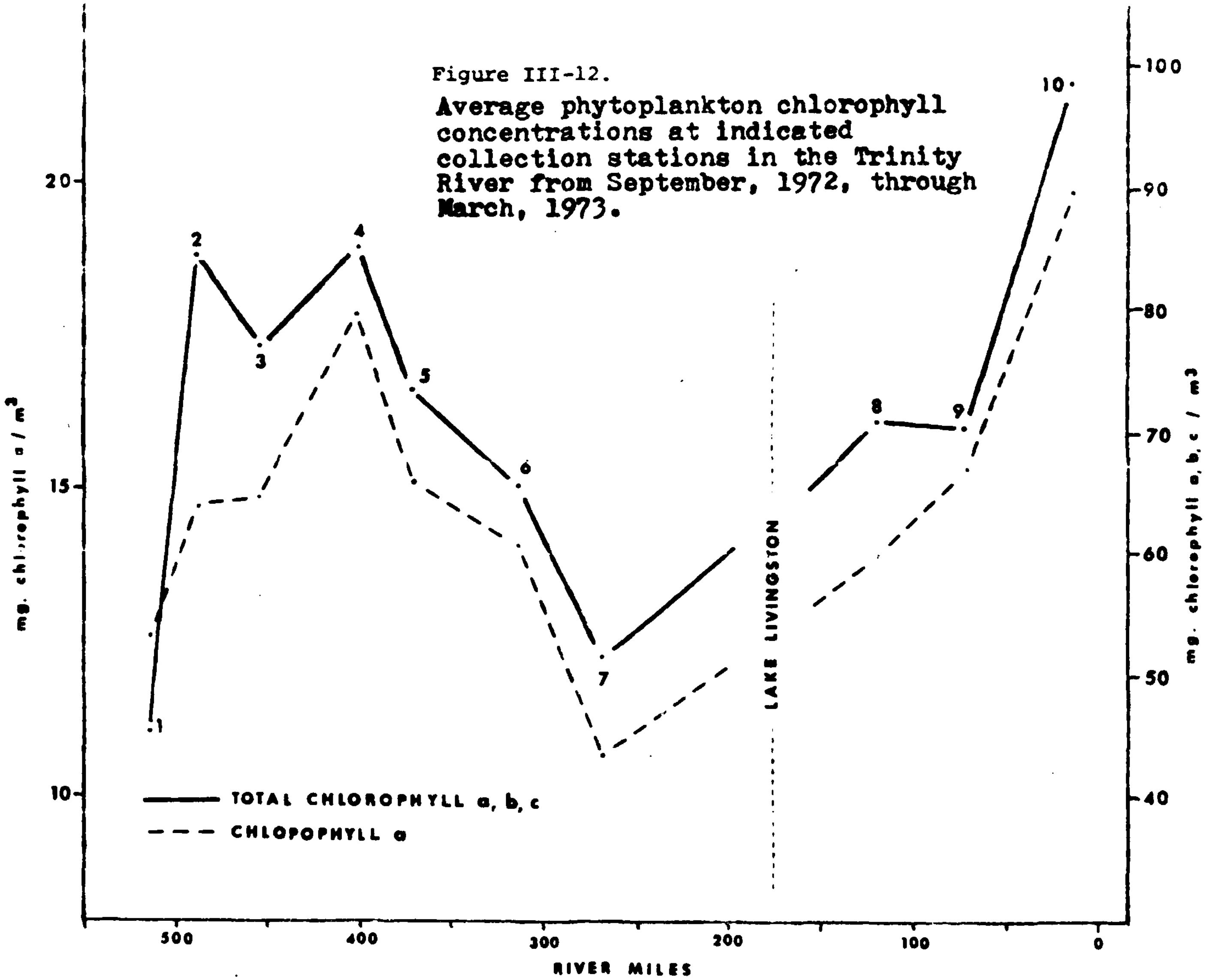


Figure III-12.
Average phytoplankton chlorophyll concentrations at indicated collection stations in the Trinity River from September, 1972, through March, 1973.

The relatively low phytoplankton population at Stations 1 and 2 are probably caused by excessive input of organic pollution upstream. Hynes (1971) points out that in severe organic pollution where de-oxygenation of the water occurs, all algae may be eliminated. However, if some oxygen remains immediately below the sewage outfall, the algae are first reduced in numbers then increase downstream. Toxic industrial effluents released upstream may also have an impact on the phytoplankton density at Station 1. Murphy, et al. (1971) have identified toxic effluents from a chemical plant, a railroad yard, and metal etching plant.

The effluent from the metal etching plant upstream from Station 1 was found to be consistently very acid and bioassay studies showed the effluent to be quite toxic: "Direct discharge of the effluent into the Trinity River would have serious effect on all living organisms." (Murphy, et al., 1971). Erratic results from BOD (eg. Low values) and occasionally with coliform analyses (e.g. No coliform organisms) coupled with a low average phytoplankton biomass, suggest a possible toxic factor at Station 1.

In view of the excessive input of organic matter above stations 1 and 2, it is reasonable to assume that the increase in phytoplankton biomass downstream from these stations was due to the release of nutrient salts from bacterial action on organic matter.

The average phytoplankton biomass value declines from Station 4 to Station 7 above Lake Livingston. Hynes (1971) reports the phytoplankton peak downstream from a sewage outfall declines rapidly. The reduction may be due to declining nutrients, dilution as the volume of the river increases, or because large populations of algae are inherently unstable. Average nitrate and phosphate values do not appear to be limiting between Stations 4 and 7, with a nitrate peak at Station 6 and with the average orthophosphate concentration slightly increasing between Stations 5 and 7.

The decrease in phytoplankton between Stations 4 and 7 may have been due to heavy grazing pressure from herbivorous zooplankton. Figure III-15 indicates a sharp increase in zooplankton which graze on algae, beginning at Station 4 and peaking at Station 6. The phytoplankton show a concurrent decrease, in a classic preditor-prey relationship. Raymont (1963), Bigelow, Lillick and Sears (1940) have demonstrated that zooplankton grazers can, very

extensively and very rapidly, reduce a phytoplankton crop, despite tremendous algal production. Clark (1939) with reference to phytoplankton production, stated: "Copepods in fact regulate the plant production."

The reduced phytoplankton biomass at Station 8 may be due to reduced nitrogen and phosphorus or possibly to the velocity of the water. Station 8 is approximately 5 miles below the dam at Lake Livingston and was often characterized by high flow rates because of water released at the dam. Williams (1964), on the basis of a five year study, has shown that heavy stream flow is a prime factor in controlling phytoplankton production. Galstaff (1924), Rzoska, et al. (1955), and Cushing (1964) have observed the effects of dams and turbulent areas in reducing plankton populations. Although the nutrients do not rise substantially at Station 10, a significant rise in average phytoplankton biomass was observed, as revealed by cell counts and by chlorophyll analyses. It might also be pointed out that a concurrent rise in zooplankton numbers also occurred. The increase in phytoplankton may be related to reduced flow, which is characteristic of that portion of the river. Hartman (1965) reports the development of higher concentrations of phytoplankton in the Ohio River is partly dependent on slow to moderate rates of flow.

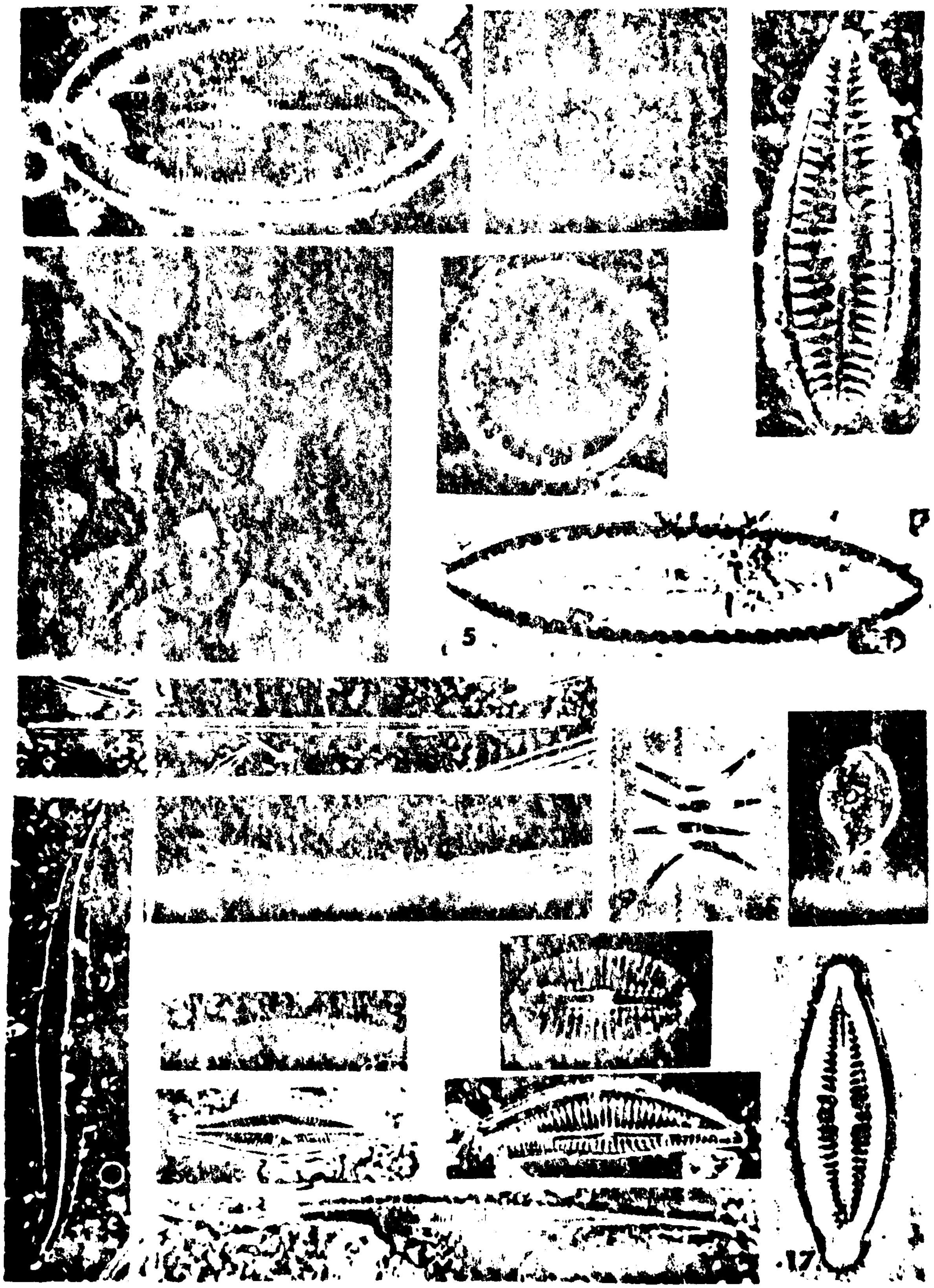
The phytoplankton community structure from Station 1 through 7 is that generally associated with waters polluted with sewage. At Stations 1 through 7, the phytoplankton community was typically dominated during the study period by members of the Division Chlorophyta, with the genera Chlorella, Scenedesmus, Chlamydomonas, and Micractinium being most common. The genera Euglena and Phacus, members of the Division Euglenophyta, are also common from Stations 1 through 7, with the diatom species (Division Chrysophtya) Nitzschia palea, Navicula cryptocephala, Gomphonema angustatum and Gomphonema parvulum also being common.

Palmer (1969) evaluated the algae listed by 110 workers as being tolerant to organic enrichment and sewage. The most tolerant genera were Euglena, Oscillatoria, Chlamydomonas, Scenedesmus, Chlorella, and Nitzschia. The most tolerant species were Euglena viridis, Nitzschia palea, Stigeoclonium tenne and Oscillatoria tenius. Generally Chlorella, Chlamydomonas and Scenedesmus are very common in sewage oxidation ponds.

The high ammonia levels characteristic in the river near the Dallas-Fort Worth area, probably select for

Plate III-01. Representative phytoplankton collected in the Trinity River, Texas

1. _Cocconeis_ sp.
2. _Micractinium_ sp.
3. _Gomphonema angustatum_
4. _Pediastrum_ sp.
5. _Surirella linearis_
6. _Cyclotella meneghiniana_
7. _Synedra ulna_
8. _Melosira granulata_
9. _Scenedesmus acuminatus_
10. _Phacus longicauda_
11. _Nitzschia palea_
12. _Diploneis smithii_
13. _Navicula cryptocephala_
14. _Cymbella ventricosa_
15. _Gyrosigma_ sp.
16. _Nitzschia acicularis_
17. _Gomphonema parvulum_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Chlorella, which is dominant in many of the stations above Lake Livingston. Preferential uptake of ammonia by *Chlorella* species is quite well established (Ludwig, 1938; Pratt and Fong, 1940; Schuler, Diller, and Kerslen, 1953; Syrett, 1962). According to King (1970) CO levels in the water may influence the presence of the genus *Chlamydomonas*, an alga also common in many of the stations above Lake Livingston.

Williams (1964) lists seven genera that are the most important genera in the major rivers of the United States as: *Cyclotella*, *Stephanodiscus*, *Synedra*, *Melosira*, *Nitzschia*, *Scenedesmus*, and *Chlamydomonas*. In the same publication, Williams points out that *Nitzschia*, *Scenedesmus* and *Chlamydomonas* become seasonally important in late summer and fall.

Hartman (1965) in a study of a eutrophic region of the upper Ohio River, found the genera *Chlamydomonas*, *Ankistrodesmus*, *Scenedesmus*, *Pediastrum*, *Micratinium*, *Crucigenia* and *Dictyosphaerium* were dominant.

The green filamentous alga *Cladophora* was frequently found in abundance attached to submerged stones and wood surfaces from Stations 1 through 7. Blum (1956) reports this species to be associated with organic pollution.

The phytoplankton community structure is influenced by water quality. The centric diatoms appear, in this study, to reflect the degree of recovery of water quality. The Division Chlorphyta dominates the phytoplankton community from Stations 1 through 7 and pinnate diatoms are the most common type of diatom. However, as water quality improves at Stations 6 and 7 the centric diatoms become frequent. At Stations 8, 9, and 10, the diatoms dominate the phytoplankton community, with the centric diatoms more common than the pinnate forms. Stations 8, 9, and 10 all reflect relatively high water quality. The most common centric diatom species found in this region of the river were *Melosira distans*, *Melosira granulata* and *Cyclotella glomerata*.

A checklist, including the relative abundance of periphyton diatoms may be found in Appendix III-06. *Gomphonema parvulum* and *Nitzschia palea* were generally the dominant species of diatom collected in periphyton samples from Stations 1 through 7, and probably reflect the high degree of organic enrichment downstream from the Dallas-Fort Worth area. Weber and Raschke (1970) found that

Gomphonema parvulum and *Nitzschia palea* indicated high levels of dissolved organics (high organic pollution). Butcher (1947) and Fjerdinstad (1964) both report the two diatoms to be associated with polluted waters. Hornung (1959) reports *Gomphonema angustatum*, also present in periphyton collections of this study, to be present in highly polluted waters. Kolkwitz (1950) and Liebman (1951) have associated *Nitzschia palea* with the alpha-meso-saprobic zone of a polluted stream. Hynes (1971) also reported *Gomphonema parvulum* and *Nitzschia palea* as being characteristic of waters with high organic pollution.

Below Lake Livingston, *Cyclotella meneghiniana*, *Melosira granulata*, and *Navicula rhyncocephala* were generally the dominant species in periphyton collections at Stations 8, 9, and 10 respectively. *Melosira* and *Cyclotella* are reported by Palmer (1969) to be genera that indicate low organic enrichment. The frequent dominance of *Navicula rhynoocephala* at Station 10 may reflect the variable chloride levels in the water. Both the brackish water from Trinity Bay and the salt water effluents from Texas Gulf Sulphur contribute to the relatively high average chloride concentration of 131 ppm at Station 10. Patrick (1966) reports that *Navicula rhynchocephala* appears to prefer, or is tolerant to, high concentrations of chloride. *Diploneis smithii*, found to be frequent at Station 10, is indicative also of high chloride concentrations in freshwater, according to Williams (1964).

Periphyton Species Diversity Index Values

The results of species diversity index analysis are given in Table III-07. The paucity of the data was caused by frequent and prolonged flood conditions in the study area, which usually resulted in the loss of the periphyton sampler. Diversity Index values ranged from a low of 0.5 at Station 2 to a high of 3.2 at Station 10. The interpretation of the diversity index values are based on the work of Wilhm and Dorris (1968) who suggested that diversity values of less than 1.0 indicate heavy pollution, values of 1.0 to 3.0 indicate moderate pollution, and values greater than 3.0 indicate clean water. Diversity Index values from Station 1 to Station 2 may be interpreted as a heavily polluted region of the river, with values at Station 3 averaging 1.3, interpreted as moderate pollution and would suggest that recovery of water quality begins in this region. This interpretation should be made with extreme caution because of the paucity of data, and in view

Table III-07. Diversity index values for all periphyton samples taken from the Trinity River

Station	October, 1972	January, 1973	March, 1973
1	0.85	1.5	
2	0.5	0.8	
3	0.9	1.3	1.7
4	1.9	2.2	
5	2.3	2.5	
6	2.1	2.5	
7	2.8	2.0	
8	2.6	2.4	
9	1.9	2.3	2.1
10 upstream	3.2	2.2	2.6
10 downstream	2.7	2.9	2.8

of the fact that two of the higher index values at Station 3 were obtained during winter months in high water conditions. A Diversity Index value of 0.9 for Station 3 was obtained in October during more "normal" discharge conditions. Periphyton diversity index values in this study show an improvement in water quality at Station 4, with an average of 2.0, reflecting moderate pollution. McCullough (1972) obtained a diversity index range from 0.8 to 2.2 at Station 4 with an average value of 1.5, indicating moderate pollution. Although some impact from the NIPAK, Inc. Effluent was detected in the Tennessee Colony Study (McCullough, 1972) no detectable impact in this study could be discerned. Benthic macroinvertebrates show an average diversity index value of 0.8087 at Station 4, which would be interpreted as heavy pollution, but this is an improvement over the upstream Station 3 whicdiversity index values at Stations 5 through 7 reflect moderate pollution n had an average benthic macroinvertebrate diversity of 0.3367. Periphyton and no significant impact could be discerned from the confluence of the Trinity River with Richland, Chambers, and Tehauacana creeks.

Below Lake Livingston diversity values are variable ranging from 1.9, moderate pollution, to 3.2 indicating clean water. Station 10 which is subject to the influence of industrial effluents and salt water intrusion does not reflect this in diversity index values. No significant difference in values could be seen comparing the upstream and downstream diversity at Station 10. Because saltwater has a density greater than fresh water, the effect of salt water intrusion may be greatest on the benthic macroinvertebrate community, with an average index value of 1.4988 at Station 10.

Primary Productivity

Results of gross primary productivity determinations at the study sites are given in Table III-08, and range from a low 349 mgC/m²/day at Station 2 to a high of 10, 292 mgC/m²/day at Station 7. The mean productivity values are given in Figure III-13, and reflect a low of 1323 mgC/m²/day at Station 10, while Station 7 produced a high average of 7511 mgC/m²/day. The average primary production rate at the study sites below Lake Livingston were all below 2000 mgC/m²/day, while only Station 1 above Lake Livingston produced an average below 2000 mgC/m²/day. Stations 3, 5, and 7 were all above an average of 3000 mgC/m²/day with Station 7 producing the highest average rate.

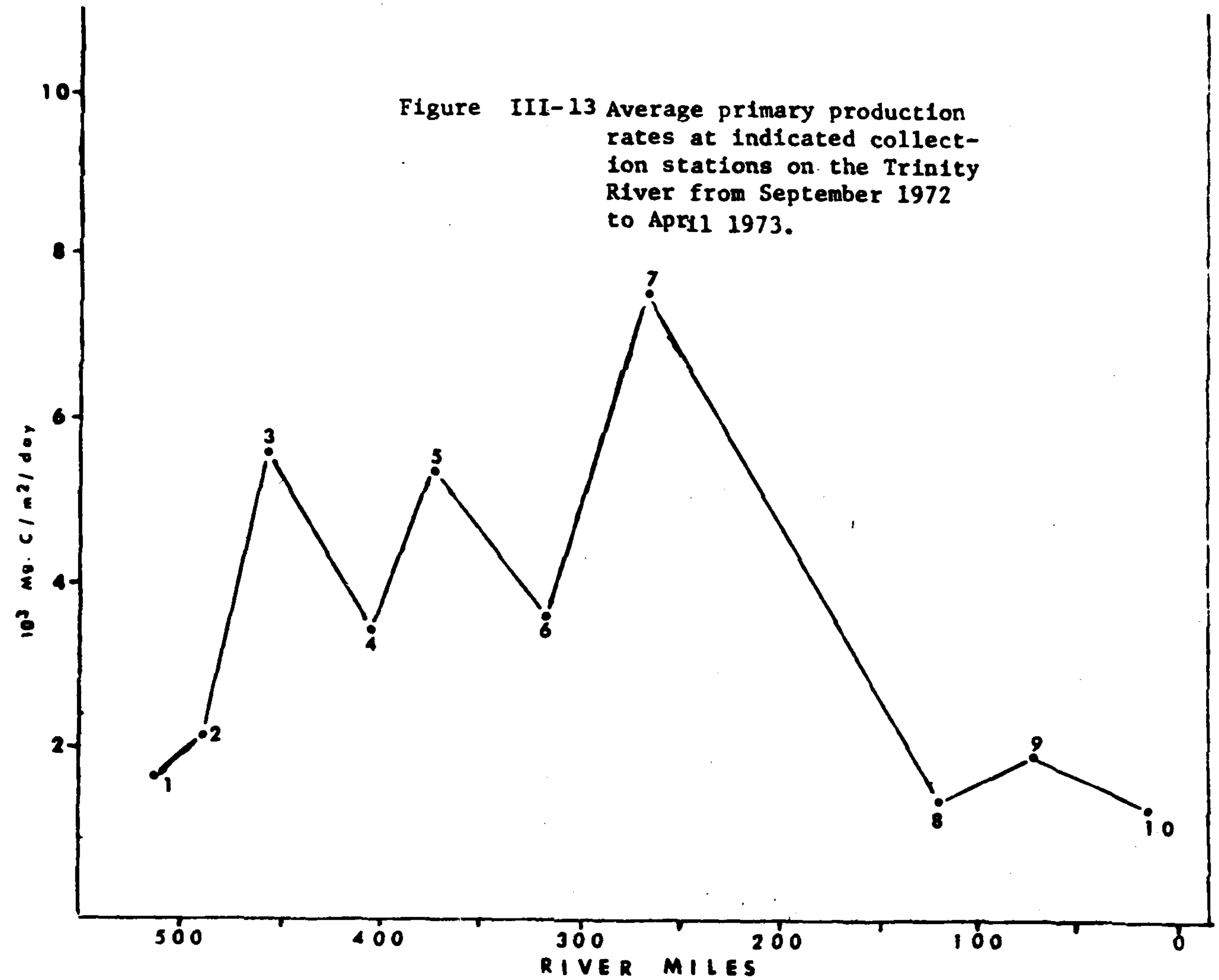

Figure III-13 Average primary production rates at indicated collection stations on the Trinity River from September 1972 to April 1973.

Table III-08. Some primary production rates at study sites on the Trinity River from September 1972 through April 1973

Station	Date	Productivity ($mgC/m^2/day$)
1	3-23-73	2,827
	1-25-73	492
2	3-23-73	4,045
	1-29-73	349
3	4-14-73	3,912
	4-27-73	7,430
4	10-4-72	4,231
	11-9-72	2,517
5	2-17-73	2,170
	3-9-73	8,430
6	10-18-72	6,391
	2-10-73	709
7	10-6-72	10,292
	1-20-73	4,730
8	9-23-72	3,038
	10-21-72	992
	11-11-72	449
9	10-7-72	2,511
	12-1-72	1,364
10	10-6-72	902
	11-4-72	1,519
	12-2-72	1,550

studies of the rate of primary production are not as common in lotic waters as in lentic water. A comparison of the range in productivity rates for the Trinity River are made with other river studies (Table III-09). The Trinity River values are comparable to the rates for other polluted rivers such as the values reported for the White River, Indiana; River Lark, England; and the Ohio River. It might be pointed out that the Trinity River values were determined during fall, winter, and spring months while the high values obtained in comparable river studies were made in summer months. It is the opinion of this writer that the Trinity River primary production rates would far exceed those values reported for other rivers had most of the determinations been done in the summer months.

The low average primary productivity rates at Station 1 and 2 are probably due to reduced phytoplankton biomass caused by heavy domestic sewage discharge upstream of these stations. Stations 3 through 7 appear to be the most productive region of the river, probably due to the downstream release of nutrient salts (e.g., NO_3 - PO_4) from organic matter and the stimulating effect this usually has on phytoplankton growth. However, the correlation between phytoplankton biomass and productivity has some discrepancies. The highest average primary production rate was recorded for Station 7 however the highest average phytoplankton biomass occurred at Station 4. Station 10 produced a relatively high phytoplankton biomass, but the average production rate did not increase proportionately at that station.

Many variables affect primary production rates, such as highly variable meterological conditions on days when productivity data was collected, turbidity, nutrients, river flow, and many other factors. The cause of variations in productivity rates in this study would, therefore, be difficult to determine.

Strickland (1965) reports there may be wide discrepancies between phytoplankton biomass and primary production rates. A large standing crop of algae may be photosynthesizing at a relatively low rate, or a low standing crop may display vigorous growth characteristics and a high rate of production (Verduin, 1956).

Vollenweider (1969) reports the P/B ratio, or Production/Biomass used by many Russian authors, may vary from zero (a completely inactive population) to some upper limit which is determined by inherent properties of the organism.

Table III-[illegible]. A comparison of some primary production rates in rivers

Source	Reference	Gross Productivity (gC/m²/day)
Trinity River, Texas September - April	This study	0.3 - 10.2
Itchen River, England	Odum (1956)	.12 - 4.3
Ivel River, England	Edwards & Owens (1962)	.99 - 5.4
Silver Springs, Florida	Odum (1957)	
Spring		10.8
Winter		2.4
Headwaters area		5.1
Neuse River, N. Carolina	Hoskin (1959)	.09 - 3.0
Blue River, Oklahoma	Duffer & Dorris (1966)	
Limestone Bed		2.1
Granite Bed		6.6
Sand Bed		0.9
San Marcos River, Texas	Hannan & Dorris (1970)	0.7 - 8.4
Ohio River	Woods (1965)	
July		0.6
August		0.5
October		1.1
White River, Indiana Polluted Recovery Zone July	[illegible]	17.8
River Lark, England Polluted May	Butcher, et al. (1930)	12.2

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Another factor which may bear upon the Production/Biomass discrepancy is the photo-heterotrophic activity of some algal species. Stations 3 through 7 were generally characterized by an abundance of *Chlorella* and *Chlamydomonas*. Parker (1971) has shown that *Chlorella vulgaris* and *Chlamydomonas eugametos* may function as heterotrophs or photo-heterotrophs in nature. Therefore, it is conceivable that a high phytoplankton biomass might exist mostly as a heterotrophic population using organic matter in the water as an energy source and carrying on little photosynthesis.

Available carbon may have also been significant in affecting the variations in production rates. King (1970) has suggested recently that carbon rather than phosphorus or nitrogen is the chief limiting nutrient in the production of algae. Bacterial oxidation of organic matter will produce CO_2 which the algae could use in the synthesis of organic matter. Burlew (1953) has shown in culture studies CO_2 enrichment stimulates productivity of algae. King (1970) has also shown that in waste oxidation ponds, the dominance of *Chlorella* and *Chlamydomonas* can be predicted by CO_2 levels, so that CO_2 may also be important in regulating the phytoplankton community structure.

Production rates in this study are probably limited by color. The FWPCA (1968) reports that color in excess of 50 units may limit photosynthesis and have a deleterious effect on aquatic life, particularly phytoplankton and benthic organisms. Average color values exceeded 50 units at all stations with peaks at Stations 6 and 7. Turbidity also limits primary production above Lake Livingston. FWPCA (1968) recommends that warm water streams not exceed 50 JTU. Values in excess of 50 JTU in warm water streams affect phytoplankton photosynthesis, fish production and benthic production. All stations above Lake Livingston exceeded 50 JTU, with only Station 8 and 9 averaging turbidity below 50 JTU. FWPCA (1968) points out that effective photosynthetic production of oxygen requires a minimum of 10% of the incident light. Secchi disc transparency, which usually represents the depth at which 5% of the incident light penetrates, was commonly only one foot or less at stations above Lake Livingston, thus reflecting a very reduced euphotic zone.

Benthic Analysis

Intermittant pollution, sometimes not discernable by periodic chemical and physical tests, may have a

significant effect on fresh-water organisms. Extreme conditions may be much more important to the aquatic community than average chemical and physical values. Because of this, the benthic community is very useful in monitoring environmental conditions. These organisms are relatively immobile, and have prolonged aquatic stages which allow a complex community structure to develop. In general, organisms are much more sensitive to changes in their environment than are chemical tests, thus they may react strongly to very small concentrations of pollutants. A periodic release of a toxic substance perhaps impossible to find by periodic analysis, may have an impact on the benthic community long after it has been carried downstream. Wilhm and Dorris (1968) have developed a very valuable technique in assessing environmental changes by analyzing changes in diversity in the benthic community. The diversity of the community is determined using the equation:

$$d = -\sum_{1}^{S} (n_i/n) \log_2 (n_i/n)$$

where (d) is the diversity index, (n_i) are the number of individuals in all species in the sample. Goodnight (1973) has interpreted diversity index values in benthic studies and states"...that values of diversity index less than 1 are indicative of heavy pollution, values from 1 to 3 indicate moderate pollution, and values above 3 are found in clean water areas."

A list of organisms collected in the benthic study with numbers and percent composition of the sample are given in Appendix III-07. The results of species diversity analysis for each benthic sample taken from the Trinity River are given in Table III-10 and Figure III-14 is a graph of the average diversity index figures by station.

With reference to the interpretation of diversity index values by Goodnight (1973), the average index implies a high degree of pollution from Station 1 through 4 and the remainder of the stations reflect moderately polluted waters. As a general trend, the diversity index increases downstream through Station 8. The exception to this progression, Station 2, is seen to have a relatively high figure for the October sample. This figure is probably explained by the number of different species of gastropods, some of which appear to be pulmonate or land snails washed into the river. The index figures for most stations appear to be rather stable with the exception of Stations 4 and 5, considered by this researcher to be "recovery" stations,

Table III-10. Diversity index figures for all benthic samples taken from the Trinity River from September, 1972 through March, 1973

Station	1	2	3	4	5	6	7	8	9	10
September	------	------	------	-------	------	1.3953	2.2200	*	1.0810	*
October	0.9446	1.8310	0.3622	0.3110	1.2252	1.4192	1.9060	1.9760	1.2900	1.5850
November	0.3910	*	0.8802	1.0437	0.2352	1.3710	------	------	1.5000	1.2788
December	------	------	------	0.7675	------	------	1.9646	2.2530	2.1736	1.0892
January	0.4754	0.4532	0.0000	1.3710	1.5850	1.2870	2.0000	2.5956	1.5488	2.2129
February	0.2017	0.6698	0.2205	------	2.2536	2.1937	2.3606	*	2.2129	2.5576
March	0.3901	1.2244	0.2205	0.5504	1.5438	1.7265	2.8554	------	------	0.2695
AVERAGE	0.4746	1.0446	0.3367	0.8087	1.3686	1.5654	2.2178	2.2749	1.6344	1.4988

------ indicates no sample taken.
* see tables for explanation.

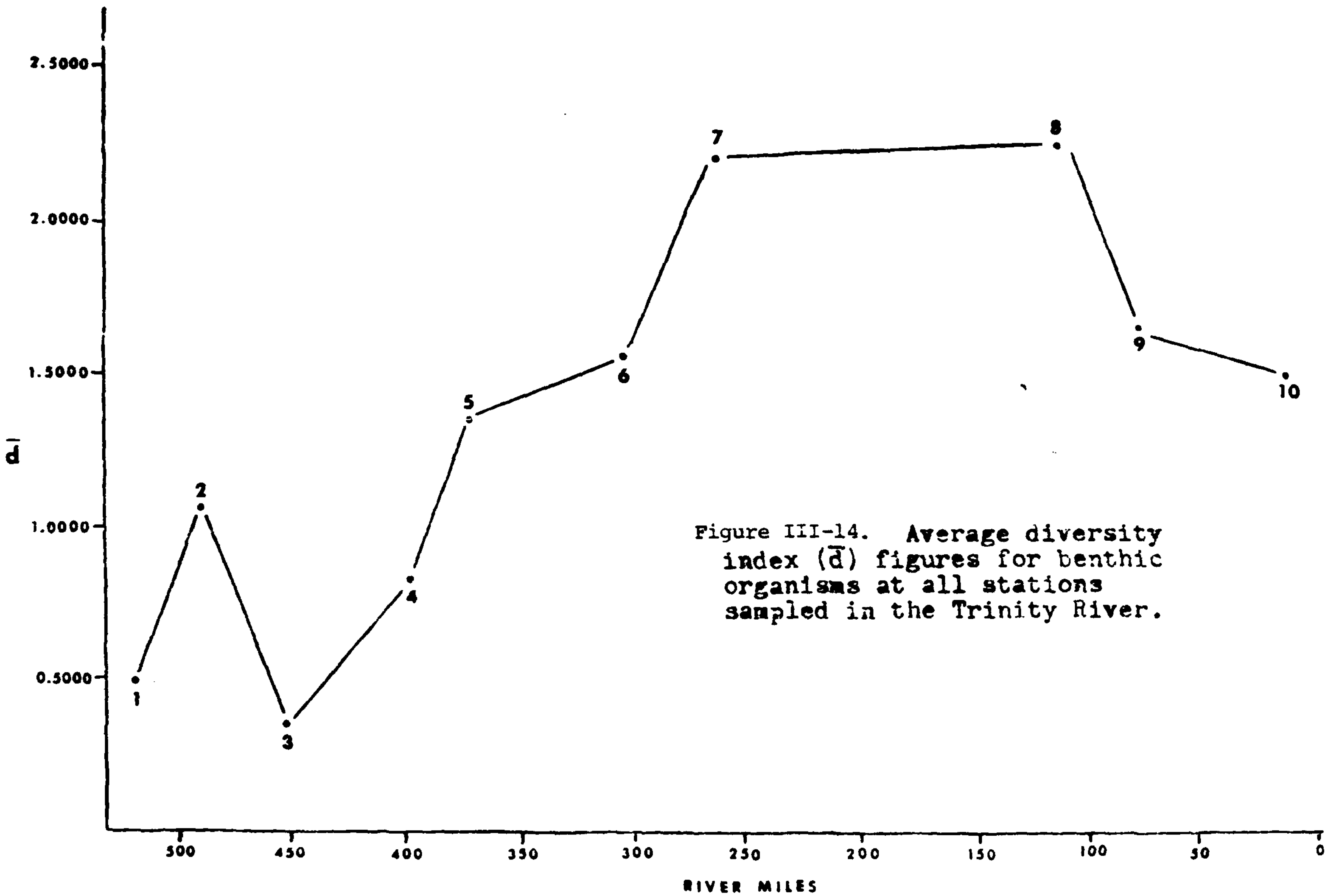

Figure III-14. Average diversity index ($\bar{d}$) figures for benthic organisms at all stations sampled in the Trinity River.

therefore easily influenced by the type and amount of pollution from upstream, flood conditions, flow rate, and other such physical and chemical factors. Also, there is the above-mentioned deviation in Station 2, and an unexplained low figure for March at Station 10, where the community structure resembled that of the highly polluted Stations 1 through 3. The low value for Station 10 could have been caused by salt water intrusion, toxic industrial effluents, high water flow, seasonal effects or other factors. An average diversity value calculated without the March index is given in parenthesis in Table III-15.

In the analysis of the benthic community structure, notice was taken of the presence or absence of well-known species indicative of certain levels of water quality. At "highly polluted" Stations 1 through 3, bottom samples generally consisted of a layer of decaying detritus (in some cases evidence of untreated sewage) over thick black "sludge". With few exceptions, pollution-tolerant groups are the only species present (Tubificidae, Chironomidae, pulmonate gastropods). At these stations the diversity index values are consistently low. Use of the suggested method of comparison of relative percentage of oligochaetes to total biota (Goodnight, 1973) is quite revealing in the river, particularly at Stations 1 through 3. Goodnight (1973) concluded that 80% or more oligochaetes indicated a high degree of organic or industrial pollution, 60-80% constituted doubtful conditions and below 60% indicated good water conditions. With only two exceptions, the percentage of tubificids present at Stations 1 through 3 were above 80%. Of the two exceptions (between 60% and 80%) one was in the presence of large numbers of other pollution indicators and one was in the case of one sample with a low total number of organisms.

At "recovery stations" 4 and 5, clay and rocks or small pebbles prevailed in the bottom samples. In addition to the species at the above three stations, leeches, sometimes listed by authors as being associated with pollution tolerant organisms, were collected. The only clean water organism added to the species list from Stations 4 and 5, is the caddis fly larva of the insect order Trichoptera. Gaufin (1956) mentions that gill breathing insects, such as caddis flies, in a stream indicates high water quality. The numbers of tubificid worms and chironomid larvae (indicators of pollution) are generally lower, creating a slightly higher species diversity. Percentage of oligochaetes rose above 80% only twice and above 60% only once.

Stations 6 and 7 reflected still higher average diversity index figures indicating more extensive recovery. The soil type at these stations was usually clay and/or fine sand. There appeared in this area such clean-water forms as gill-breathing molluscs, gill-breathing insect larvae (Hexagenia sp.; Trichoptera; Odonata; both Zygoptera and Anisoptera), and decapod crustacea. Tubificid worms and chironomid larvae declined to some of their lowest numbers, and occurrences were recorded here of amphipods and of the fresh-water endoproct Urnatella gracilis Leidy. Percentage of oligochaetes was usually very low, only twice rising above 60% at Station 6. Members of the Unionidae (fresh-water clams) were frequently found at Stations 6 and 7. Goodnight (1973) reports that the unionidae are not found in polluted streams; thus their presence indicates favorable conditions.

Station 8 would, by species listings and diversity index figures, be included with Station 7 as the least polluted portion of the river. All of the stations downstream from Lake Livingston reflect "moderate pollution" conditions with values between 1.0 and 3.0. However, the benthic community diversity probably does not reflect the much improved water quality, especially at Stations 8 and 9. In the opinion of this writer, the index values are unusually low for the quality of water in this region of the river. Station 8 average diversity was 2.74, highest average for the river, but the station was very inconsistent in species composition and density of organisms. The greatest number of species were found at Station 8, but this was only one collection. On two occasions, repeated Ekman dredge samples yielded no visable organisms. In the one sample in which oligochaetes were reported, the percentage was low. The inconsistency is probably caused by a rather unstable substrate of mostly shifting sand and a highly variable rate of flow. Station 8 is located below the dam of Lake Livingston and is subject to flow conditions ranging from no flow up to as much as 40,000 CFS during one period of this study. Also, the ranges in temperature of the water varied, depending on whether water was being released. The samples which produced the greatest number of species were taken during early winter when there had been a long period of moderate flow in the river. Low yield came during, or just after, major water releases. Blanz et al., (1969) reported that water released from Beaver Dam in Arkansas had an adverse effect on the development of the benthic community due to a turbulent substrate. Neel (1963) found a more stable substrate in natural streams permitted a wider variety of organisms.

Plate III-02. Representative benthic organisms collected in the Trinity River, Texas

1. Polychaete - collected at Station 10
2. Tubificid worm (Annelida; Tubificidae)
3. Mayfly nymph (Ephemeroptera; *Hexagenia* sp.)
4. Caddisfly larva (Trichoptera)
5. Midge larva (Diptera; Tendipididae=Chironomidae)
6. Biting midge larva (Diptera; Ceratopogonidae)


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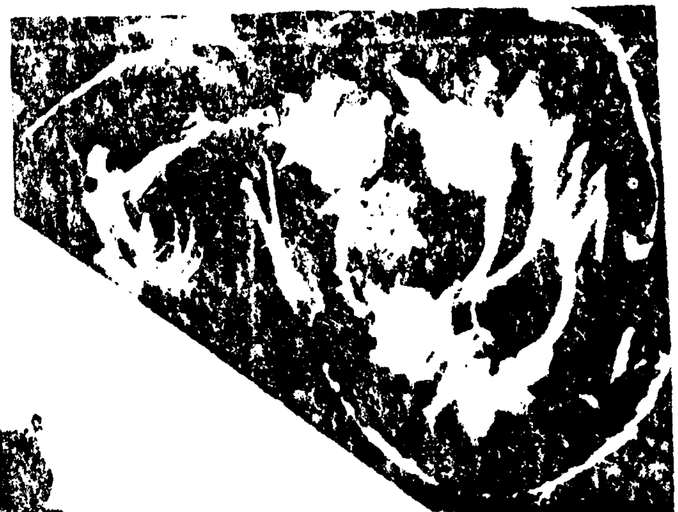
Plate III-03. Representative benthic organisms collected in the Trinity River, Texas

1. Amphipeda
2. Dragonfly nymph (Odonata; Anisoptera; *Gomphus* sp.)
3. Fresh-water entoproct, *Urnatella gracilis* Leidy



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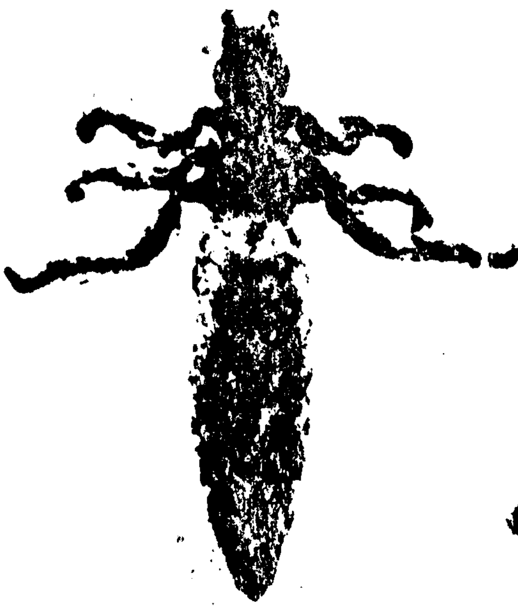

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The benthic community diversity seems low at Station 9, compared with the water quality data in that porion of the river. Again the bottom is mostly shifting sand and the flow is usually rapid. The diversity index values remained relatively constant with an average of 1.63. Species composition at Station 9 remained largely clean-water forms, with the exception of the October sample in which there was a puzzling combination of the largest number of individuals of the genus Hexagenia, an indicator of high water quality, with the largest number and percentage of tubificids which rose to above 60%.

With an average of 1.49, Station 10 had the lowest average benthic community diversity of the stations below Lake Livingston. The depth of the water is up to 7 meters and the bottom is fine black clay with detritus. The benthic community is exposed to industrial effluents from a plant adjacent to this station, which consists mostly of salt water and sulfate, and the community is exposed to a salt water "wedge" due to tide activity at Trinity Bay. Station 10 was very inconsistent with respect to numbers of individuals in each sample, ranging from no organisms present in one sample to very profuse populations in other samples. Between these extremes are many combinations of clean water organisms and pollution-indicator organisms, of fresh-water organisms and marine organisms. The percentage of tubificids rose once above 80% of the organisms collected in one sample.

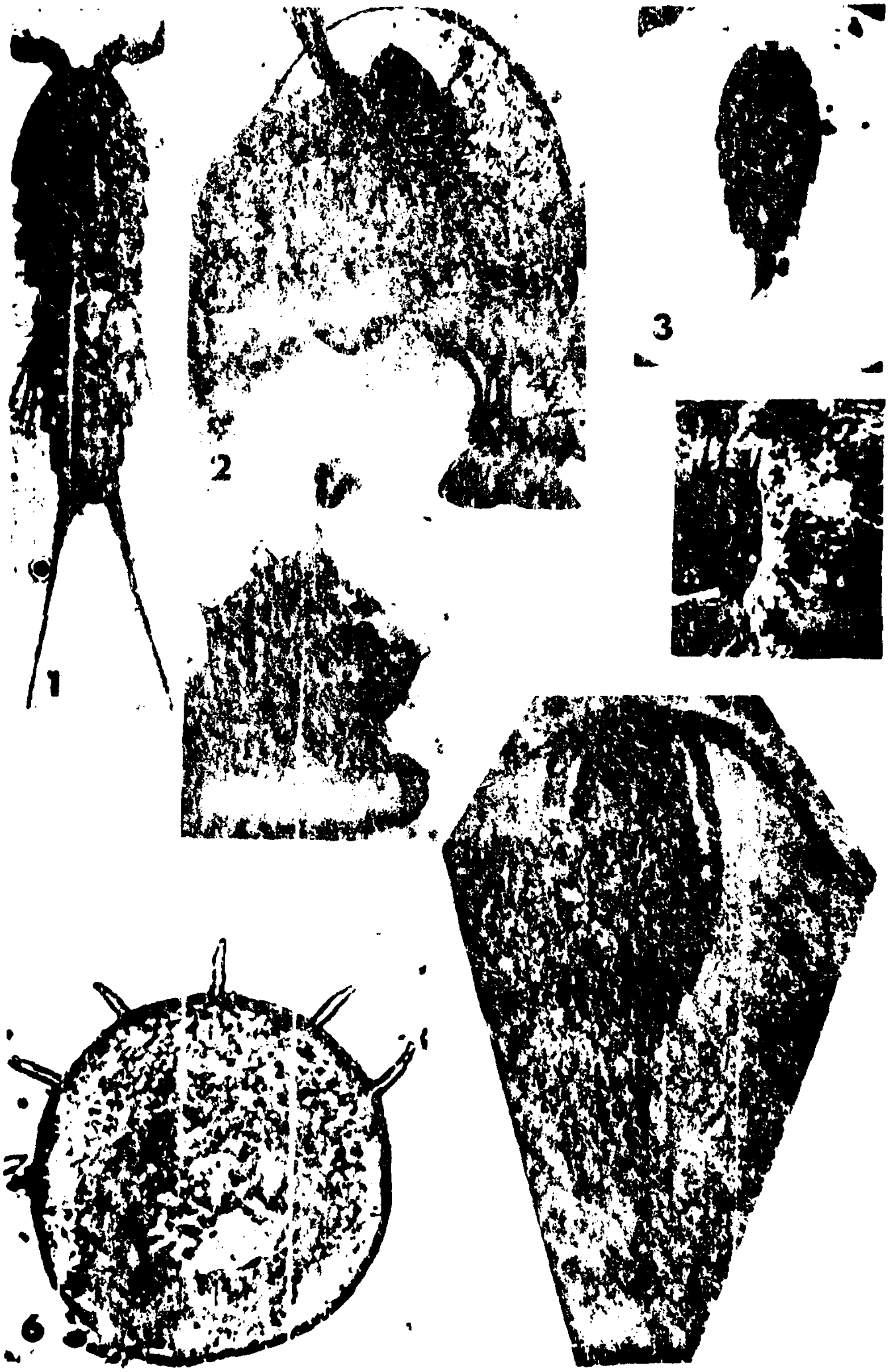
At Station 10 some sporadic but very significant collections were made of apparently marine or estuarine species of two different phyla, these being at least two species of polychaete worms and an amphipod not included in available fresh-water keys, but closely resembling members of the marine family Corophiidae having greatly enlarged second antennae. Also, an annelid was twice collected at Station 9 which is tentatively identified as the oligochaete Branchiura sowerbyi Bedd, because of distinctive pairs of gills on approximately the last forty segments.

Zooplankton Analysis

There has long been a controversy over whether rivers support a true plankton community. It has been strongly suggested that plankton originate in tributaries or in quiet bays and side arms and are washed into the river at periods of high water. After an initial rise in plankton in the river due to this flush-out, the composition and

Plate III-04. Representative zooplankton collected in the Trinity River, Texas

1. Harpacticoid copepod
2. Cladocera (_Bosmina_ sp.)
3. Cyclopoid copepodid
4. Rotifer (Branchionidae)
5. Rotifer (_Keratella_ sp.)
6. Testacean, (_Arcella_ sp.
7. Cyclopoid copepod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numbers are supposedly changed by selective elimination of standing-water species and by dilution. These changes may leave some true plankton species along with some strays from other habitats in an inherently unstable community subject to constant change (Hynes, 1971).

A list of zooplankton organisms collected and their abundance is given in Appendix III-08. According to Hynes (1971), river zooplankton typically includes the Protozoa Arcella and Difflugia, with ciliates in large numbers in polluted waters. In this study, Arcella was numerous in the upper end of the Trinity River and Difflugia in the lower end. Ciliates, as well as flagellates, some amoebae, and some suctorians, were numerous in the river, particularly at Stations 1 and 2, but were rarely counted because of the necessity for preservation of the samples well in advance of counting. Hynes (1971) states that, in contrast to the condition of lakes, the zooplankton in rivers is dominated by planktonic rotifers, and the crustacea are not numerous and are relatively unimportant, usually species of Cyclops and Bosmina. Reference to the relative abundance of rotifers and crustacea in Figure III-15 shows that the above statement generally holds true in the Trinity River, with crustacea rising to importance only at Station 7 and below Lake Livingston at Station 8. Direct flow of water from the lake environment may contribute to the crustacea dominance at Station 8. Dominant rotifers were several members of the family Brachionidae and "Keratella-like" species, a counting category which included Keratella spp. And occasional individuals of the genera Kellicottia and Notholca. Other rotifers counted from samples were Filinia, Lecane, Monostyla, Philodina and Rotaria.

The planktonic crustacea were primarily Copepoda and Cladocera. The Cladocera were usually dominated by the genus Bosmina with Moina, Simocephalis, Pleuroxis striatus Schodler 1863, Chydorus spaericus (O.F. Muller) 1785, Daphnia and Alona guttata Sars 1862, being less common. The cyclopoid copepods included Tropocyclops prasinus Fischer 1860, Cyclops spp., Mesocyclops edax (Forbes) 1891. Calanoid copepods and two species of harpactacoid copepods were also found.

Average diversity index (d) figures for zooplankton (Table III-11 and Figure III-16) seem rather erratic. However, if one takes into account the fact that the lower figure at Station 6 is probably due to the extremely high rotifer count in September and October, an upward trend would otherwise be seen through Station 7 (indicating a less polluted aquatic condition). The lower diversity at

Table III-11. Diversity index figures for all zooplankton samples taken from the Trinity River from September, 1972 through March, 1973

Station	1	2	3	4	5	6	7	8	9	10
September	------	------	------	------	------	0.4505	2.1090	1.8522	------	------
October	1.3750	1.9353	2.1648	2.1037	2.0060	0.1301	2.3500	2.0633	2.5816	1.1977
November	2.1541	1.0831	2.5064	1.9834	2.7493	2.4496	------	------	2.8884	2.5939
December	------	------	------	2.5771	------	------	2.2832	2.5214	2.2868	1.0376
January	1.1163	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.5238	1.2738
February	2.3306	2.3793	2.4734	------	2.5622	2.6174	2.5582	1.7389	1.9571	1.8321
March	2.4117	2.7211	1.8929	1.3039	1.4284	2.1855	2.6935	------	1.4768	2.0998
AVERAGE	1.8775	2.0663	2.1996	2.0554	2.2262	1.6904	2.4237	1.8454	2.1191	1.6725

------ indicates no sample taken

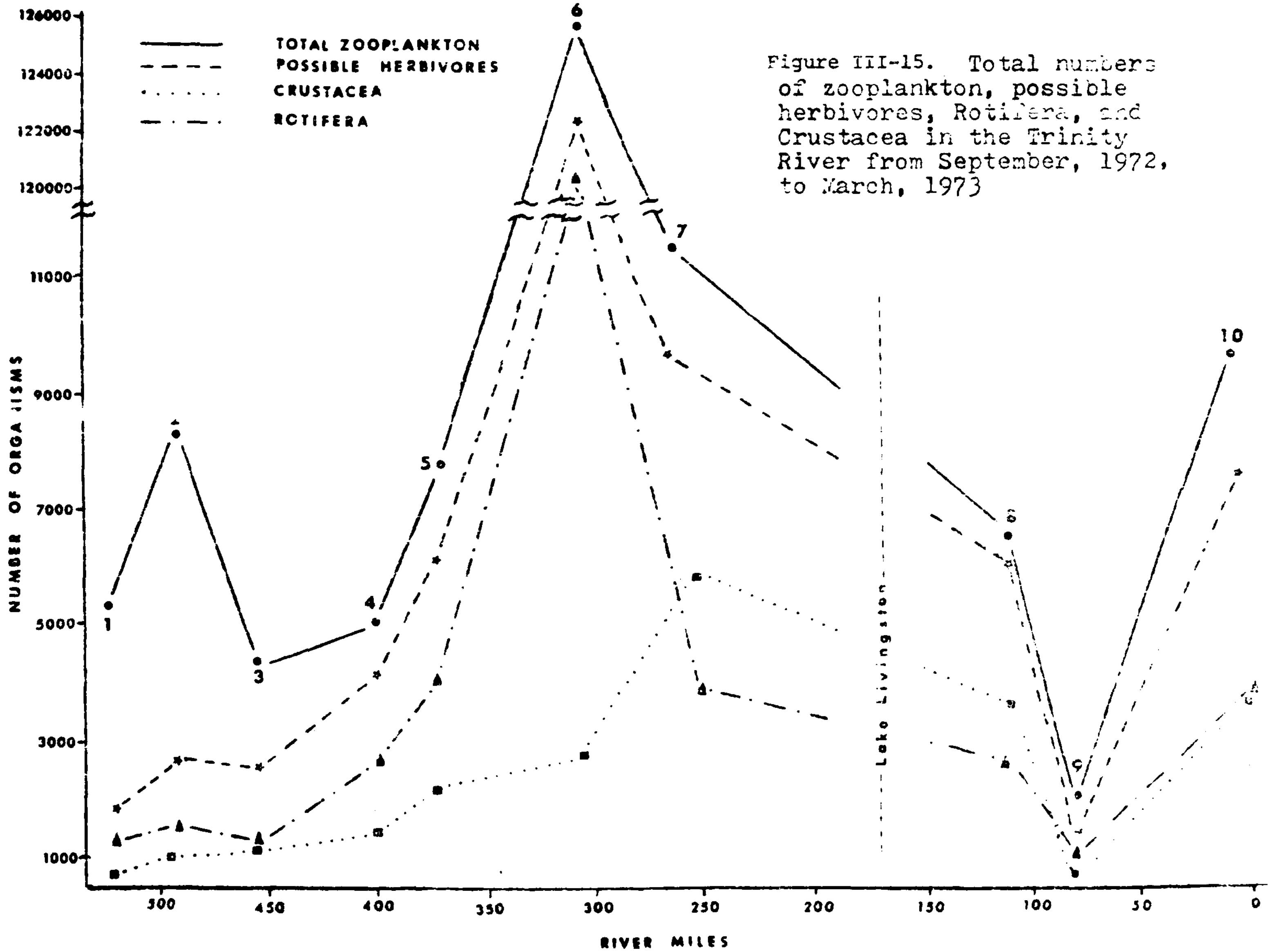


Figure III-15. Total numbers of zooplankton, possible herbivores, Rotifera, and Crustacea in the Trinity River from September, 1972, to March, 1973

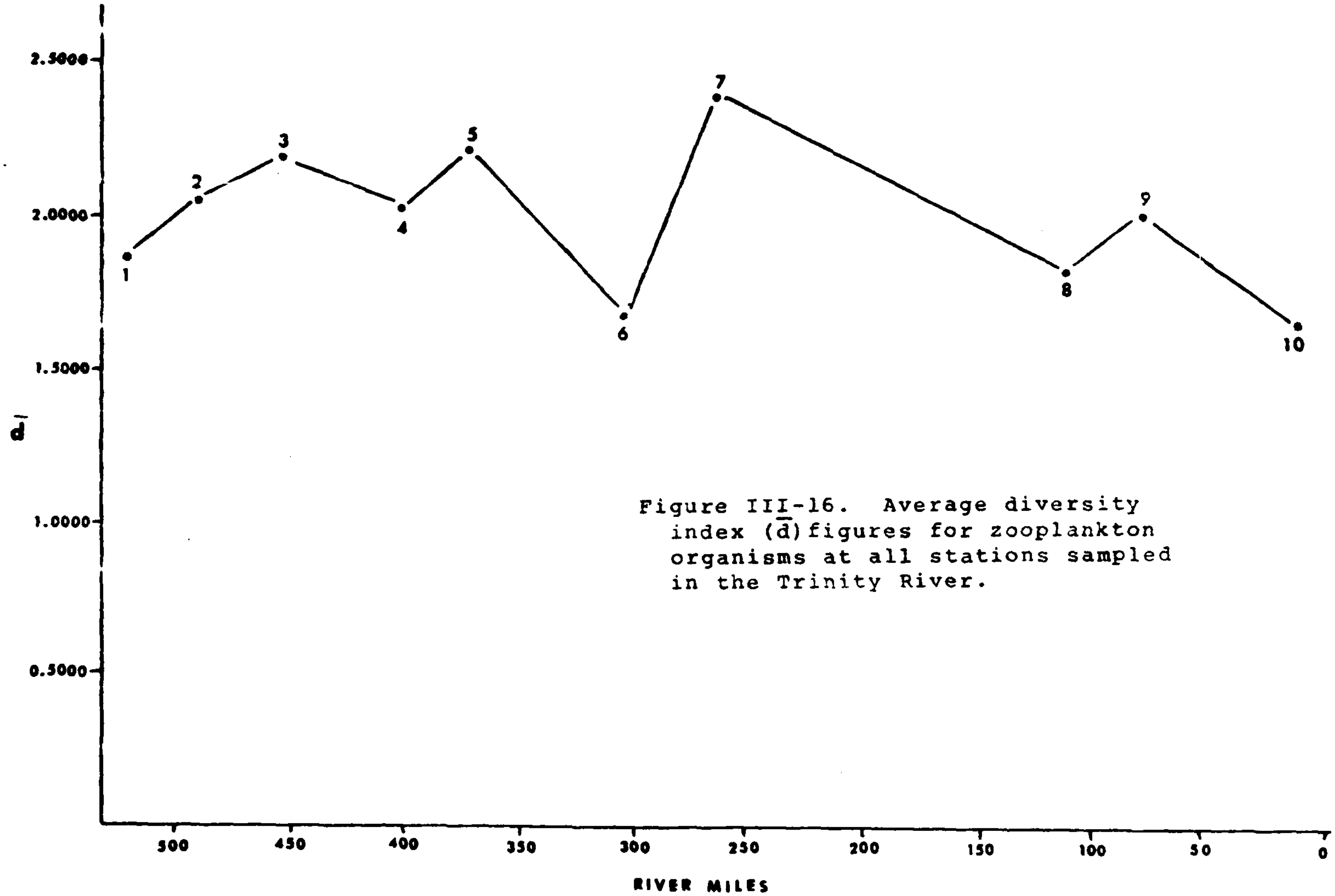


Figure III-16. Average diversity index ($\bar{d}$) figures for zooplankton organisms at all stations sampled in the Trinity River.

Station 8 was probably due to the stress on the zooplankton in changing from a lentic to a lotic situation.

Zooplankton diversity rose at Station 9, but fell again at Station 10. Even though the average total number of zooplankton rose at Station 10, the number of species became reduced, possibly being influenced by special conditions present at the mouth of the Trinity River such as reduced flow rate and salt water intrusion.

At the "highly polluted" stations 1 through 3, it is apparent from Figure III-15 that much of the zooplankton population is made up of nonherbivorous species of protozoa. Where organic pollution is severe and bacteria populations are high, Hynes (1971) reports that bacteria-eating protozoa, particularly the ciliates, dominate as opposed to the algae-eating genera.

At Stations 4 and 5, considered in this study to be "recovery" stations, total zooplankton population and herbivore population rose simultaneously, with the rise in herbivores due mainly to increased numbers of rotifers (Figure III-15). Algae-eating genera of protozoa, such as Stentor, were frequently observed. It should be noted that at Stations 4 and 5 the average phytoplankton biomass was higher than at any other station on the river.

Zooplankton populations rose sharply downstream from Station 5, reaching their highest levels at Stations 6 and 7. The effect of this expanding population of herbivores is probably seen in the rapid decline in the average phytoplankton biomass in this region of the river. The largest number of zooplankton species occurred at Station 7 where, incidentaly, there also occurred one of the most diverse benthic communities. Station 6 contained rotifer populations of several hundred thousand in September and October, influencing the average number disproportionately. Without these "blooms" the average population at Station 6 would fall on an upward slope between Stations 5 and 7.

Below Lake Livingston the zooplankton population levels declined through Station 9, to the lowest figures in the river, rising sharply in number at Station 10. The phytoplankton populations also rose at Station 10. Zooplankton species diversity at Stations 8, 9, and 10 showed the opposite trend compared with the populations at those stations. Station 8 probably had imposed upon it the influence of the lake environment just above it. Station 9 is rather unusual in its comparatively greater width with

very shallow water and riffles. The influences at Station 10 have been previously alluded to.

Coliform Bacteria Analysis

The bacteriologic examinations of samples are used to determine the sanitary quality and suitability for general use of the water. The methods are intended to indicate the degree of contamination of the water with wastes from human or animal sources. The tests have been for the detection and enumeration of indicator organisms. The coliform group has been used as such an indicator organism. Extensive studies have been done to establish the significance of the coliform group densities as criteria of the degree of pollution. The sensitivity of the historically older multiple tube fermentation test has been increased by developments in the bacteriologic techniques and culture media. The multiple tube fermentation test has been accepted as a standard method, and recently the membrane filter has also been accepted as a standard method.

In studying the bacteriological aspects of the Trinity River, both the multiple tube fermentation test and the membrane filter analysis were employed. In both procedures, the density of coliform organisms was reported as organisms per 100 ml. The fecal streptococci on the membrane filter tests were also reported as organisms per 100 ml. The multiple tube counts are determined as most probable numbers (MPN) using a table (Standard Methods, 1972), and the membrane filter analysis are reported as membrane filter counts (MFC). The results of total coliform, fecal coliform, and fecal streptococcus are given in Appendix III-09 and Figures III-17 and III-18.

In studying the results from the ten station on the Trinity River, the stations on Loop 12 and at Rosser had consistently high counts. The lowest most probable numbers were obtained at the lowermost three stations. The other stations had MPN which varied according to the results from the multiple tube fermentation test. Station 1 which was located near Highway 360 went from a maximum MPN of greater than 240,000 coliforms/100 ml to an apparent absence of coliforms. This data could be attributed to the toxicity of some chemical effluent or some similar type influence on the microbial ecology. In studying the multiple tube fermentation results, it is also important to point out that the presence of *Escherichia coli* was confirmed on all studies where there was acid and gas producton. Occasionally this confirmation involved several transfers

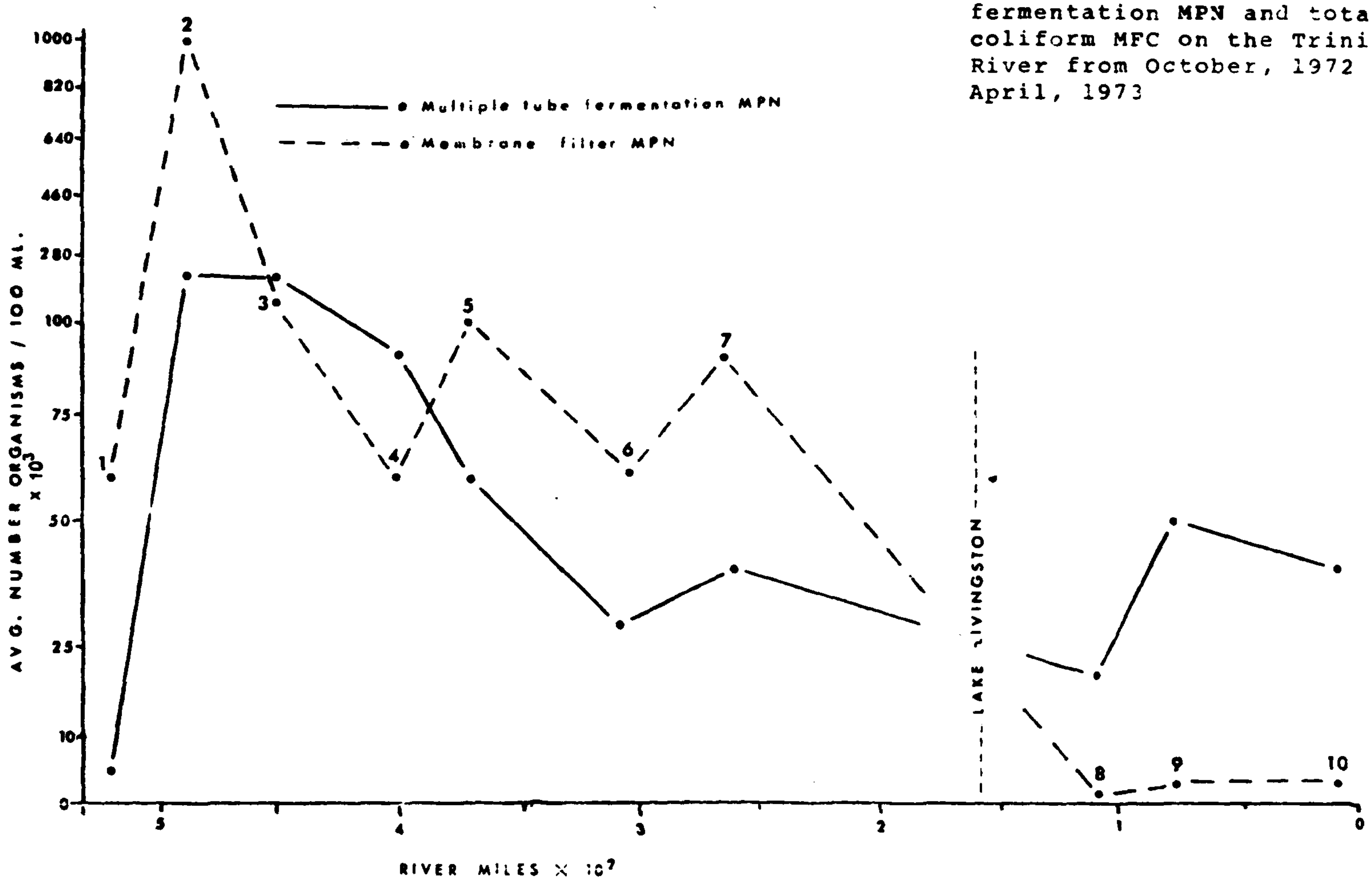


Figure III-17. Multiple tube fermentation MPN and total coliform MFC on the Trinity River from October, 1972 to April, 1973

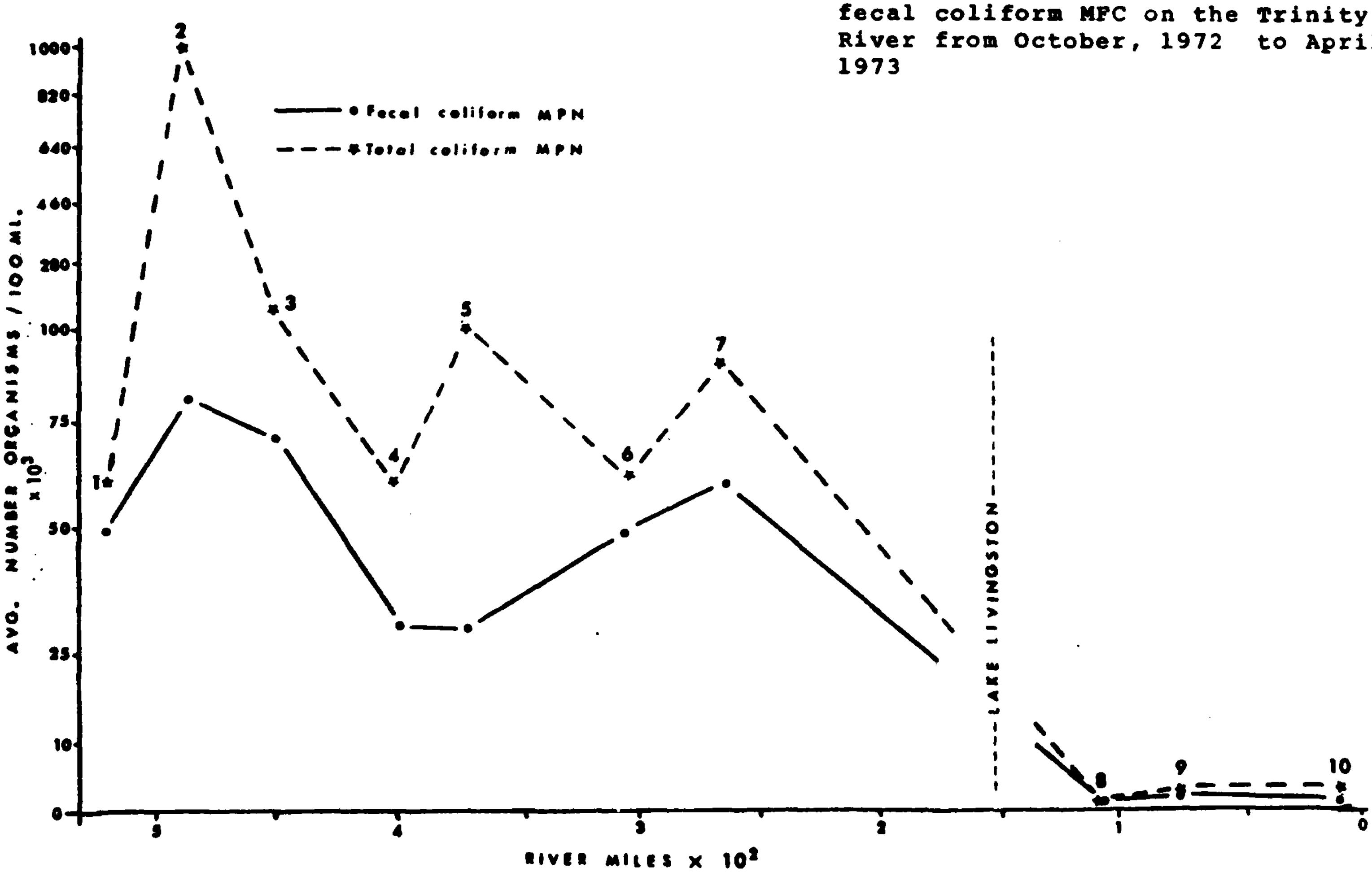


Figure III-18. Total coliform MFC and fecal coliform MFC on the Trinity River from October, 1972 to April, 1973

on eosin methylene blue agar to obtain a green metallic sheen. The inability to obtain this sheen at first can be attributed to the overgrowth by other bacterial organisms

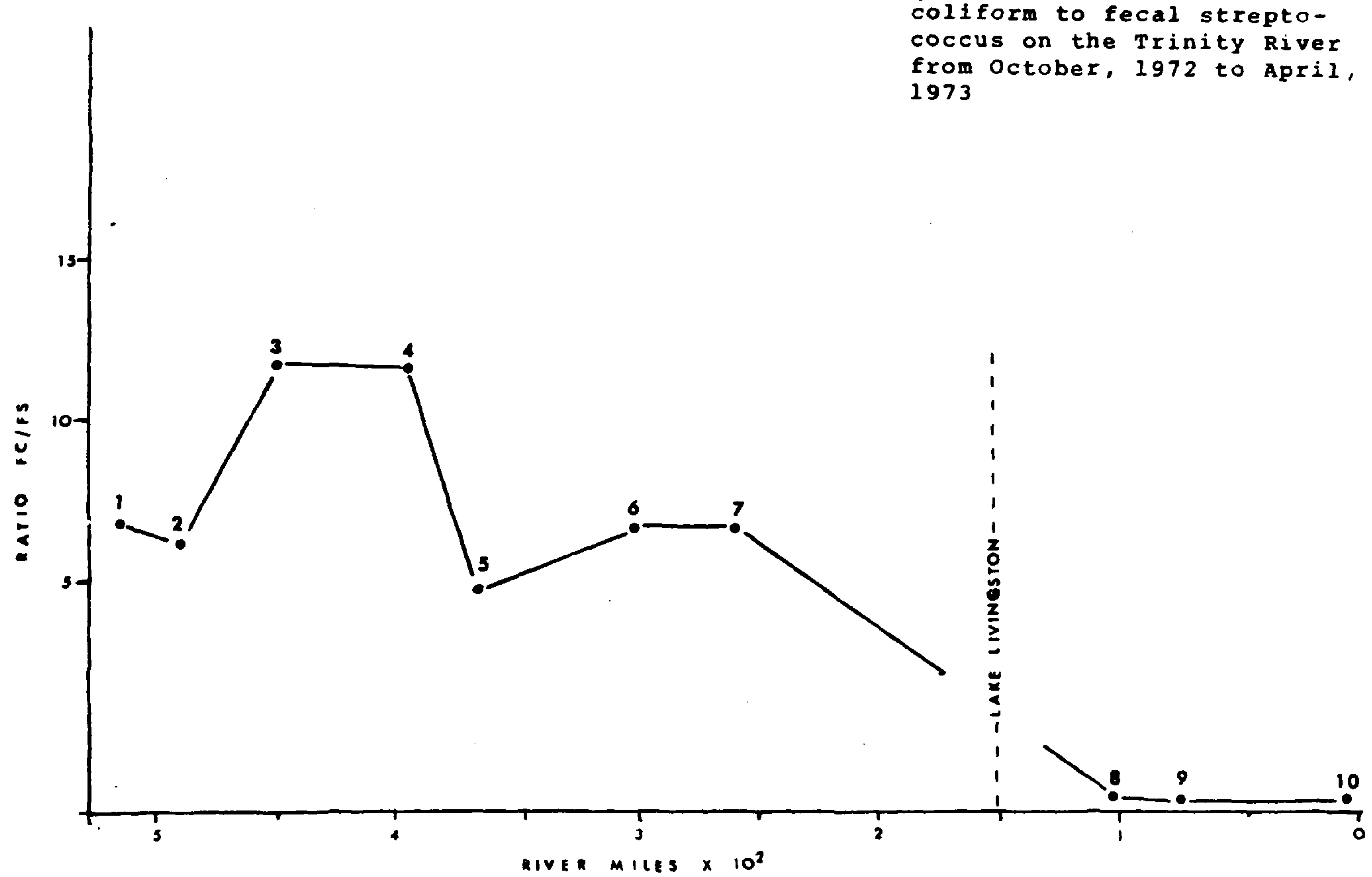
Since the most probable number determinations were only enumerated to 240,000 coliforms/100 ml according to the tables in Standard Methods (1971), the total coliform membrane counts were important in estimating organisms above this point. The membrane filter counts involve a direct counting method. This direct plating technique eliminates to a large extent the synergistic reaction which could produce acid and gas in the multiple tube method. Figure III-18 gives an approximate relationship for these two methods. The highest averages on the membrane filter total coliform counts occurred at Station 2 which is located at Loop 12. The lowest counts were obtained below Lake Livingston. These low counts or absence of counts at Stations 8, 9, and 10 might be attributed to a dilution or settling out factor.

The fecal coliform and the fecal streptococcus counts are an important value in determining the possible source of contamination. Ratios of fecal streptocci to fecal coliform which are 4 and above indicate a possible human contamination (Geldreich and Kenner, 1969). Stations 1 through 7 had average ratios above 4. Stations 8, 9, and 10 had ratios below 4 for the study period. Ratios of the type that were obtained at these stations indicate sampling at a distance away from the original source of contamination (Figure III-19).

In order to further clarify the fecal coliform and fecal streptococci groups, a classification study was done. Although most strains of coliforms are symbiotic in relation to the animal gut, the main organisms were varieties of _Escherichia coli._ The fecal coliform test results are always given in addition to total coliform results so that an evaluation can be made of the authenticity of data, since fecal coliform counts should be smaller than total coliform data. However, the fecal coliform data can also be used to determine if the organisms involved are of fecal origin. The selectivity of this test is to a large extent based on the elevated water bath temperature and the culture media.

On Stations 1 through 7 the classification study showed the presence of _Escherichia coli_ mainly, but also indicated the presence of _Enterobacter aerogenes_ and _Citrobacter freundii_ in smaller percentages than

Figure III-19. Ratio of fecal coliform to fecal streptococcus on the Trinity River from October, 1972 to April, 1973



Escherichia coli. Stations 8, 9, and 10 were studied for classification of fecal coliforms in December and January which were the only dates when significant counts were found. The only organism found at these stations was *Escherichia coli.*

The fecal streptococci classification included *Streptococcus faecalis, Streptococcus bovis,* and *Streptococcus equinus. Streptococcus faecalis* was the main organism found at all stations. The other two streptococci were found occasionally at the upper seven stations. However, in December *Streptococcus bovis* was found Station 9. Some characteristics of these organisms are that they will not multiply in the water and some have a rapid die-away rate in water (Geldreich and Kenner, 1969). Fecal streptococci are native to the gut of warm-blooded animals. Eighty percent or over of human fecal streptococcus bacteria is included in the *Streptococcus faecalis* group (Biological Analysis of Water and Wastewater, 1972). Cows and horses are possible sources for *Streptococcus bovis* and *equinus.*

It is important in the evaluation of these methods to recognize the limitations. One factor that has to be considered in a study such as this one is the turbidity of the water tends to interfere with the bacterial growth on the membrane filter. Also in using the multiple tube fermentation method, high populations of some bacteria can interfere with the growth of the coliform organisms. There is also the possibility of synergistic action resulting in acid and gas production in the multiple tube fermentation test.

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APPENDIX III

Appendix III-01. Water quality data from Trinity River from September 1972 to April 1973
(Values in milligrams per liter except as indicated)

(-- no sample)

Date	Temp. °C	Oxygen	Turbidity (JTU)	Color (CU)	Conductance**	Secchi Depth***	pH	eH (m.V)	PO_4
Station 1									
10-9-72	25.8	2.7	35	80	990	1.0	7.88	--	28.00
11-2-72	16.0	4.3	310	90	395	--	7.30	100	3.00
11-28-72	15.0	5.5	19	60	835	1.0	7.60	200	4.10
1-15-73	8.0	9.2	50	70	875	1.0	7.45	250	3.50
2-10-73	7.2	12.0	115	81	650	.3	7.35	50	5.00
3-3-73	14.2	5.5	7	62	945	.1	7.60	100	3.80
4-8-73	16.0	5.0	29	50	840	1.1	7.51	50	4.10
AVERAGE	14.6	6.3	81	70	790	0.6	7.53	120	7.36
Station 2									
10-9-72	27.0	1.9	77	175	970	.7	7.60	160	39.00
11-2-72	16.0	4.2	450	95	440	--	7.05	220	3.70
11-28-72	15.0	2.9	68	100	870	.5	7.20	400	6.60

Appendix III-01 (cont.)

(--no sample)

Date	NH_3 N	NO_2 N	NO_3 N	Cl	SO_4	Discharge CFS	POC	DOC	BOD	SOD
				Station 1						
10-9-72	20.00	.425	2.99	105	135	95	4.00	6.63	6.8	---
11-2-72	2.30	.400	1.30	30	65	1210	6.83	8.18	8.6	---
11-28-72	3.50	.450	2.55	75	150	143	3.43	6.00	3.0	---
1-15-73	10.25	.250	1.35	75	130	221	5.75	7.50	6.7	---
2-10-73	4.20	.370	1.58	50	140	434	6.29	8.68	4.2	---
3-5-73	10.00	.535	2.22	90	125	294	4.16	6.06	11.2	---
4-8-73	4.60	.300	1.85	85	125	--	--	--	5.6	---
AVERAGE	7.84	.390	1.98	73	124	399	5.08	7.18	6.6	---
				Station 2						
10-9-72	19.50	.310	2.09	100	140	362	12.25	11.81	19.8	---
11-2-72	3.00	.240	1.00	35	89	2560	10.12	5.82	6.4	---
11-28-72	15.00	.375	1.80	80	200	574	10.29	10.00	17.8	---

Appendix III-01 (cont.)

(--no sample)

Date	Temp °C	Oxygen	Turbidity (JTU)	Color (CU)	Conductance**	Secchi Depth***	pH	eH (m.V)	PO_4
				Station 2 (Cont')					
1-15-73	7.0	8.0	35	62	722	.8	7.51	250	10.00
2-10-73	7.0	10.8	102	125	555	.3	7.32	100	2.80
3-3-73	15.0	4.5	16	85	795	.1	7.32	250	8.00
4-8-73	16.2	3.4	20	106	785	1.0	7.40	100	6.54
AVERAGE	[illegible]	5.1	110	106	733	0.6	7.34	210	10.94
				Station 3					
10-9-72	25.0	1.4	48	128	910	1.5	7.65	140	35.00
11-2-72	16.0	3.7	480	130	365	--	7.25	100	3.60
11-9-72	18.0	1.3	60	100	805	--	7.35	250	11.00
11-28-72	12.0	3.7	25	90	775	.5	7.30	300	5.10
1-15-73	5.0	8.4	68	35	740	.5	7.40	300	5.90
2-10-73	6.6	11.4	175	130	493	.2	7.46	100	.90
3-3-73	14.0	3.4	36	100	635	.5	7.41	250	7.75

Appendix III-01 (cont.)

(--no sample)

Date	NH_3 N	NO_2 N	NO_3 N	Cl	SO4	Discharge CFS	POC	DOC	BOD	SOD
				Station 2 (Cont')						
1-15-73	16.00	.111	1.59	55	125	731	7.34	8.38	7.8	27.5
2-10-73	2.30	.200	2.00	35	145	2750	4.12	6.34	8.6	41.8
3-3-73	10.00	.190	1.16	70	140	754	7.38	9.00	8.8	27.9
4-8-73	6.00	.330	2.05	75	160	--	--	--	4.7	--
AVERAGE	9.40	.251	1.67	64	142	1288	8.58	8.56	9.9	32.4
				Station 3						
10-9-72	21.00	.007	..67	140	130	340	7.20	9.56	9.6	--
11-2-72	3.50	.200	1.00	30	73	4470	8.84	5.44	10.2	--
11-9-72	14.50	.060	.20	65	190	584	8.74	8.44	--	--
11-28-72	14.00	.275	1.70	65	175	536	6.16	7.62	10.4	--
1-15-73	9.00	.160	1.64	60	130	7090	7.80	8.75	10.5	30.3
2-10-73	1.60	.980	1.06	25	150	7899	7.30	4.50	9.8	26.4
3-3-73	7.40	.200	.70	50	89	1106	6.75	6.50	9.6	--

Appendix III-01 (cont.)

(--no sample)

Date	Temp. °C	Oxygen	Turbidity (JTU)	Color (CU)	Conductance**	Secchi Depth***	ph	eH (m.V)	PO_4
				Station 3 ¢Cont')					
4-8-73	14.9	4.9	47	80	.555	.5	7.50	--	5.85
AVERAGE	13.9	4.8	117	99	.659	.6	7.42	206	9.38
				Station 4					
10-4-72	24.0	4.1	54	70	.890	1.0	7.30	300	34.00
1122972	16.0	3.3	600	135	.410	--	7.20	120	2.70
11-9-72	16.5	4.8	110	55	.610	.5	7.45	150	3.50
11-30-72	10.0	8.1	48	155	.810	1.2	7.45	100	5.30
1-4-73	9.8	6.8	190	60	.850	--	7.20	250	2.20
1-10-73	3.0	7.8	162	75	.550	.5	7.30	350	4.60
2-10-73	6.8	10.6	195	240	.365	--	7.42	100	1.68
3-7-73	15.0	3.6	43	35	.661	.5	7.5[illegible]	200	4.00
4-8-73	15.2	3.5	47	80	.592	.7	7.45	--	4.65

Appendix III-01 (cont.)

(--no sample)

Date	NH_3 N	NO_2 N	NO_3 N	Cl	SO_4	Discharge CFS	POC	DOC	BOD	SOD
Station 3 (Cont')										
4-8-73	2.15	.190	2.25	45	80	--	--	--	5.6	--
AVERAGE	9.14	.259	1.15	60	127	3146	7.54	7.26	9.4	28.4
Station 4										
10-4-72	20.70	.240	.58	85	125	402	5.75	7.38	13.6	--
11-2-72	5.80	.320	1.70	25	73	3040	9.33	4.19	11.4	--
11-9-72	5.75	.380	1.00	45	170	779	5.38	5.00	--	--
11-30-72	14.00	.450	1.50	60	170	548	12.62	10.00	--	--
1-4-73	16.00	.800	.53	100	200	1910	3.71	5.25	--	--
1-10-73	4.20	.160	.27	37	140	--	--	--	7.0	--
2-10-73	2.40	.170	1.58	25	98	10171	6.58	4.12	6.7	--
3-7-73	8.90	2.700	.89	50	110	1275	3.00	4.00	10.9	17.1
4-8-73	6.00	.250	1.50	50	90	--	--	--	3.9	--

Appendix III-01 (cont.)

(-- no sample)

Date	Temp. °C	Oxygen	Turbi-dity (JTU)	Color (CU)	Con-duct-ance**	Secchi Depth***	pH	eH (m.V)	PO_4
				Station 4 (Cont')					
AVERAGE	12.9	5.8	161	100	.637	.7	7.36	200	6.96
				Station 5					
10-4-72	23.0	4.5	62	20	715	1.0	7.60	200	29.00
11-21-72	10.0	6.6	128	50	.681	--	7.20	300	3.00
11-30-72	9.5	8.0	60	190	780	1.0	7.50	200	4.80
1-4-73	9.5	9.8	90	65	735	--	7.70	250	3.30
1-10-73	3.0	8.0	182	60	530	.2	7.40	300	3.20
2-8-73	13.0	6.5	91	125	.610	.2	7.30	400	6.00
307-73	16.0	4.6	58	105	.645	.3	7.55	200	10.00
4-1-73	17.0	5.0	155	80	.450	.3	7.40	120	7.60
AVERAGE	12.62	6.6	103	87	.643	.5	7.46	250	8.36

Appendix III-01 (cont.)

(-- no sample)

Date	NH_3 N	NO_2 N	NO_3 N	Cl	SO_4	Discharge CFS	POC	DOC	BOD	SOD
				Station 4 (Cont')						
AVERAGE	9.30	.608	1.06	53	130	2589	6.62	5.71	8.9	17.1
				Station 5						
10-4-72	13.50	1.100	1.70	75	130	--	12.34	10.06	12.8	--
11-21-72	7.60	.340	3.41	50	130	*645	4.25	9.17	8.0	--
11-30-72	10.50	.550	1.80	65	160	--	--	--	--	--
1-4-73	15.00	2.800	1.30	80	130	*948	2.96	5.62	14.4	--
1-10-73	2.90	.095	.27	35	175	--	--	--	5.4	--
2-8-73	4.25	.360	1.08	72	87	*2510	4.92	5.63	16.2	12.3
3-7-73	6.75	3.300	1.50	45	130	--	4.16	5.94	4.5	11.7
4-11-73	2.50	.336	1.71	30	60	--	--	--	5.5	2.8
AVERAGE	7.87	1.11	1.60	56	125	1368	5.73	7.28	9.5	8.9

Appendix III-01 (cont.)

(-- no sample)

Date	Temp. °C	Oxygen	Turbidity (JTU)	Color (CU)	Conductance **	Seechi Depth***	pH	eH (m.V)	PO_4
				Station 6					
9-26-72	26.0	2.6	38	93	915	.7	7.20	350	29.00
10-18-72	21.0	2.6	15	32	835	1.0	7.12	300	32.00
11-21-72	10.0	7.8	190	105	435	--	7.25	250	3.50
11-30-72	9.6	8.0	80	35	580	.5	7.40	150	.10
1-4-73	9.0	8.7	50	15	662	--	7.90	250	1.28
1-10-73	3.0	5.8	510	255	340	.1	7.50	200	1.35
2-8-73	13.0	9.6	170	128	400	.1	7.50	300	2.00
3-7-73	16.5	6.9	155	250	410	.2	7.65	200	3.20
4-1-73	17.0	5.4	125	130	386	.3	7.46	--	4.50
AVERAGE	13.9	6.4	148	116	551	.4	7.[illegible]	250	8.55
				Station 7					
9-27-72	26.0	6.5	62	42	800	.5	7.60	200	40.00

Appendix III-01 (cont.)

(-- no sample)

Date	NH_3 N	NO_2 N	NO_3 N	Cl	SO_4	Discharge CFS	POC	DOC	BOD	SOD
					Station 6					
9-26-72	10.00	1.220	4.22	80	150	740	3.84	6.00	--	--
10-18-72	1.50	.575	10.30	95	150	323	--	--	16.6	--
11-21-72	2.10	.320	2.68	45	80	942	2.70	3.88	5.4	--
11-30-72	2.10	.220	1.50	50	145	748	--	--	--	--
1-4-73	10.00	.350	1.45	70	130	1220	--	--	24.8	--
1-10-73	2.10	.030	.81	30	125	---	6.25	5.88	2.8	--
2-8-73	1.28	1.600	.20	20	56	2850	5.75	4.62	9.3	14.[illegible]
3-7-73	2.30	2.400	1.30	40	84	5600	5.54	5.81	5.1	5.9
4-1-73	1.23	.216	1.48	30	65	---	--	--	4.9	1.6
AVERAGE	3.62	0.77	2.66	51	109	1775	4.82	5.24	9.8	7.4
					Station 7					
9-27-72	.61	.190	.00	90	135	752	4.42	5.50	--	--

Appendix III-01 (cont.)

(-- no sample)

Date	Temp. °C	Oxygen	Turbi-dity (JTU)	Color (CU)	Con-duct-ance***	Secchi Depth***	pH	eH (m.V)	PO_4
				Station 7 (Con't)					
10-18-72	22.8	5.2	7	18	.830	1.5	7.55	--	40.00
11-21-72	11.0	9.4	185	70	555	--	7.10	350	5.25
12-5-72	10.0	88.5	55	45	595	.5	7.50	100	4.50
1-4-73	10.0	6.4	72	10	660	--	8.10	250	.70
1-10-73	3.0	5.8	510	255	.340	.3	7.50	200	1.35
2-8-73	11.5	11.0	128	112	.370	.3	7.60	300	1.45
3-7-73	18.0	6.4	240	305	.301	.1	7.65	150	1.18
4-1-73	16.5	7.3	120	200	292	.3	8.15	400	3.33
AVERAGE	14.3	7.4	153	117	527	.5	7.64	240	10.86
				Station 8					
9-25-72	26.0	8.2	33	60	.345	2.0	[illegible]	110	1.10
10-17-72	27.0	5.6	15	28	1.470	1.5	7.90	50	.22

Appendix III-01 (cont.)

(-- no sample)

Date	NH_3 N	NO_2 N	NO_3 N	Cl	SO_4	Discharge CFS	POC	DOC	BOD	SOD
					Station 7 (Cont')					
10-18-72	.03	.025	2.10	105	120	419	5.75	6.68	6.6	--
11-21-72	2.10	.180	2.30	50	125	1580	4.46	6.00	4.0	--
12-5-72	.75	.160	1.65	55	125	980	6.25	14.12	7.2	--
1-4-73	4.90	.400	1.55	90	150	1650	4.92	8.00	25.0	--
1-10-73	2.10	.030	.81	30	125	--	6.58	5.00	2.0	--
2-8-73	.92	1.250	.19	25	52	3600	4.66	3.75	8.7	33.3
3-7-73	1.55	1.550	1.15	30	66	8800	7.38	5.50	4.8	22.2
4-1-73	.85	.036	.56	25	48	--	--	--	4.0	4.4
AVERAGE	1.53	.425	1.14	56	105	2540	5.55	6.82	7.8	20.0
					Station 8					
9-25-72	.74	.032	.19	32	28	524	2.71	2.88	--	--
10-17-72	.28	.005	.02	310	98	267	5.16	6.18	7.0	--

Appendix III-01 (cont.)

(-- no sample)

Date	Temp. °C	Oxygen	Turbidity (JTU)	Color (CU)	Conductance**	Secchi Depth***	pH	eH (m.V)	PO_4
				Station 8 (Cont')					
11-21-72	13.5	11.2	15	15	.380	--	7.85	50	.28
12-5-72	10.0	11.5	15	28	.415	2.5	7.92	400	.90
122-73	9.0	11.8	5	100	.480	--	9.00	80	.58
1-10-73	8.2	9.0	210	130	.370	--	7.50	100	.50
2-24-73	10.0	13.5	27	75	.395	2.0	7.72	150	.59
3-8-73	13.5	12.5	29	145	.380	--	7.90	--	.20
3-28-73	16.[illegible]	10.8	17	85	.360	--	7.40	50	.70
AVERAGE	14.8	10.4	41	74	.510	2.0	7.92	120	.56
				Station 9					
9-19-72	32.0	8.5	15	--	.036	2.0	8.0[illegible]	180	1.00
10-17-72	28.0	4.[illegible]	22	48	.425	1.0	[illegible]	150	.54
11-14-72	16.7	12.6	80	30	335	1.0	7.90	300	.32

Appendix III-01 (cont.)

(-- no sample)

Date	NH_3 N	NO_2 N	NO_3 N	Cl	SO_4	Discharge CFS	POC	DOC	BOD	SOD
					Station 8 (Cont')					
11-21-72	.19	.015	3.10	30	45	3360	5.42	4.75	--	--
12-5-72	.25	.012	.32	55	120	1770	3.50	3.94	2.4	--
1-2-73	.53	.070	.06	45	54	640	2.42	4.19	4.2	--
1-10-73	.65	.005	.55	35	72	--	5.88	3.06	1.5	--
2-24-73	.42	.023	.63	30	51	5300	3.12	9.00	1.5	--
3-8-73	.71	.002	.60	25	60	15000	2.42	3.82	2.4	--
3-28-73	.55	.028	.79	30	23	--	--	--	1.2	--
AVERAGE	.48	.021	.70	66	61	3837	3.83	4.73	2.9	--
					Station 9					
9-19-72	.68	.005	.02	37	24	464	5.21	4.75	--	--
10-17-72	.35	.000	.02	40	35	295	1.17	3.18	8.6	--
11-14-72	.45	.002	.13	25	37	2520	3.00	3.94	--	--

Appendix III-01 (cont.)

(-- no sample)

Date	Temp. °C	Oxygen	Turbidity (JTU)	Color (CU)	Conductance**	Secchi Depth***	pH	eH (m.V)	PO_4
				Station 9 (Cont')					
12-7-72	11.0	11.6	4	25	.390	--	7.70	200	.60
1-2-73	10.0	10.8	10	100	.455	--	8.70	80	.60
2-24-73	10.5	13.0	21	70	.350	.6	7.91	210	.37
3-8-73	13.5	11.5	33	95	.340	--	7.99	20	.70
3-28073	16.0	9.6	41	75	.355	--	7.75	150	.60
AVERAGE	17.2	10.2	28	65	.335	1.2	8.01	161	.59
				Station 10					
9-19-72	34.0	8.7	5	--	2.880	2.0	8.50	390	.32
10-17-72	26.0	5.3	21	38	.400	2.5	8.65	500	.25
11-14-72	17.0	11.2	220	155	.235	1.1	7.15	150	.55
12-7-72	13.5	9.6	4	35	.380	--	7.[illegible]	120	.20
1-2-73	10.0	111.0	130	140	.550	--	8.50	80	2.90

Appendix III-01 (cont'd)

(-- no sample)

Date	NH_3 N	NO_2 N	NO_3 N	Cl	SO_4	Discharge CFS	POC	DOC	BOD	SOD
					Station 9 (Cont')					
12-7-72	.12	.005	.16	32	--	1610	3.34	6.12	2.4	--
1-2-73	.10	.020	.10	40	30	470	2.42	3.00	4.4	--
2-24-73	.45	.003	.44	40	33	5700	3.67	5.44	3.0	--
3-8-73	.65	.008	.68	45	72	15000	3.88	8.31	2.7	--
3-28-73	.55	.028	.71	35	27	--	--	--	1.1	--
AVERAGE	[illegible]	.009	.28	36	37	3723	3.24	4.96	3.7	--
					Station 10					
9-19-72	.19	.005	.00	768	135	+	3.20	3.62	--	--
10-17-72	.35	.000	.01	35	44	+	3.34	2.94	3.6	--
11-14-72	1.17	.000	.12	30	40	+	4.66	7.00	--	--
12-7-72	.42	.014	.07	35	--	+	2.17	3.12	10.8	--
1-2-73	.95	.045	.17	85	80	+	3.38	3.68	1.0	--

Appendix III-01 (cont.)

(-- no sample)

Date	Temp. °C	Oxygen	Turbidity (JTU)	Color (CU)	Conductance**	Secchi Depth***	pH	eH (m.V)	PO_4
				Station 10 (Cont')					
2-24-73	10.0	10.2	22	85	349	.6	7.90	200	.37
3-8-73	16.5	7.8	22	140	.320	--	7.81	20	.68
3-28-73	18.0	6.0	24	140	.509	[illegible]	7.98	100	.50
AVERAGE	18.1	8.7	56	105	678	1.5	7.97	195	.72

Appendix III-01 (cont.)

(-- no sample)

Date	NH_3 N	NO_2 N	NO_3 N	Cl	SO_4	Discharge CFS	POC	DOC	BOD	SOD
					Station 10 (Cont')					
2-24-73	.51	.007	.30	40	39	6400	3.29	4.94	.6	--
3-8-73	.75	.008	.50	30	60	10800	3.21	7.12	1.9	9.6
3-28-73	.74	.025	.15	30	9	+	--	--	1.0	--
AVERAGE	.63	.013	.16	131	58	8600	3.22	4.63	3.2	9.6

* Discharge at station no. 5 was approximated by subtracting the flow at Tehuachana Creek and Catfish Creek from the flow at station no. 6.

\+ Discharge not known at low stages due to tide effect.

** Conductance - Micro-mhos at 25 °C.

*** Secchi Depth - Feet

-- Indicates no sample taken.

Appendix III-02. Water quality data from Trinity River, river rise from October 23, 1972 to October 31, 1972.
(Values in milligrams per liter except as indicated)

(-- no sample)

Date	Temp. ^{o}C	Oxygen	Turbid-ity (JTU)	Color (CU)	Con-duct-ance**	pH	eH (m.v.)	PO_4
				Station 5				
10-23-72	17.0	3.3	120	310	640	7.35	100	42.00
10-24-72	21.0	.8	65	161	940	7.51	50	36.00
10-25-72	18.6	1.8	110	65	905	7.25	200	70.00
10-26-72	---	---	496	298	400	7.40	80	15.00
10-27-72	21.0	6.6	600	640	178	7.55	--	18.00
10-31-72	16.0	2.6	540	330	380	7.40	--	8.00
AVERAGE	18.7	3.0	322	300	574	7.41	110	31.50
				Station 6				
10-23-72	21.0	4.6	65	245	775	7.40	50	49.00
10-24-72	20.0	2.4	50	135	775	7.45	100	32.00
10-25-72	19.0	1.6	85	11	750	7.00	400	40.00

Appendix III-02 (cont.)

(-- no sample)

Date	NH_3	NO_2	NO_3	Cl	SO_4	Discharge CFS	POC	DOC	BOD
Station 5									
10-23-72	11.50	.400	1.50	60	160	834	10.84	7.06	16.0
10-24-72	21.00	.175	2.30	145	190	1188	8.96	9.12	18.2
10-25-72	22.00	.300	2.10	100	170	1727	6.17	5.68	8.8
10-26-72	7.00	.235	.10	30	68	2981	--	--	16.0
10-27-72	2.00	.025	.86	15	23	2982	--	--	5.6
10-31-72	5.00	.500	1.80	20	77	6076	5.18	12.42	--
AVERAGE	11.50	.273	1.44	62	115	2631	7.79	8.57	12.9
Station 6									
10-23-72	11.00	.450	3.00	90	150	744	6.75	6.88	17.6
10-24-72	13.50	.660	3.10	40	140	1260	6.38	6.62	17.0
10-25-72	9.75	.275	8.20	85	140	1800	6.42	5.18	15.0

Appendix III-02 (Cont.)

(-- no sample)

Date	Temp. °C	Oxygen	Turbidity (JTU)	Color (CU)	Conductance**	pH	eH (m.v.)	PO_4
			Station 6 'Continued					
10-26-72	--	---	620	300	815	7.30	100	34.00
10-27-72	16.0	4.0	500	220	420	7.55	--	12.00
10-31-72	15.9	2.9	360	225	350	7.60	--	8.00
AVERAGE	18.4	3.1	280	189	647	7.38	162	29.2
			Station 7					
10-23-72	22.2	7.4	62	210	655	7.50	50	35.00
10-24-72	17.0	4.8	65	142	692	7.30	150	24.00
10-25-72	19.4	1.9	47	10	680	7.20	250	20.00
10-26-72	--	---	195	220	710	7.20	180	27.00
10-27-72	16.0	1.6	270	200	690	7.22	200	26.00
10-31-72	16.8	3.4	800	420	285	7.50	000	4.00
AVERAGE	18.3	3.8	240	200	619	7.32	140	22.67

Appendix III-02 (cont.)

(-- no sample)

Date	NH_3	NO_2	NO_3	Cl	SO_4	Discharge CFS	POC	DOC	BOD
					Station 6 Continued				
10-26-72	13.50	.160	.60	80	190	3080	11.50	6.68	14.2
10-27-72	6.75	.200	.80	35	120	3180	10.25	4.50	14.4
10-31-72	4.70	.148	1.51	25	90	6470	11.46	3.94	---
AVERAGE	[illegible]	.815	2.87	59	138	2756	8.79	5.63	15.6
					Station 7				
10-23-72	.93	.700	6.10	80	125	930	7.67	5.68	6.6
10-24-73	.75	.700	5.90	95	125	971	5.75	7.30	7766
10-25-72	1.15	.015	7.30	90	98	1460	5.96	5.68	10.2
10-26-72	7.75	.070	4.00	70	110	2410	5.58	5.68	14.2
10-27-72	10.75	.140	3.50	85	125	3750	7.96	6.00	15.6
10-31-72	2.40	.070	2.00	20	72	10,300	10.20	4.12	---
AVERAGE	3.96	.282	4.8	73	109	3303	7.19	5.74	10.8

Appendix III-03. Pesticide residues and sediment composition in samples collected in the Trinity River from January 1972 to January 1973
(Pesticide residues of sediment in microgram per kilogram)

TRINITY RIVER AT ROSSER, TEXAS (BRIDGE ON STATE HIGHWAY 34)

Date	Organics %	Clay %	Silt %	Sand %	Dry Weight %	DDT	DDE
3-8-72	5.4	36	27	37	58.4	0	1.92
4-5-72	5.6	31	31	38	67.3	0	0.67
5-31-72	7.8	41	27	32	73.7	0	4.22
6-29-72	8.1	47	30	23	73.3	0	0
9-2-72	7.8	50	18	18	71.8	0	7.20
10-12-72	9.0	39	41	20	49.3	0	0
11-28-72	7.8	52	37	11	51.5	0	5.77
1-12-73	6.2	47	31	22	68.4	0	10.99
Mean	7.2	42.9	30.3	25.1	64.2	0.0	3.85
Standard Deviation	1.3	7.3	6.9	9.6	9.8	0.0	3.96

Pesticide Residues of Sediment in Microgram per Kilogram

TRINITY RIVER AT ROSSER, TEXAS (BRIDGE ON STATE HIGHWAY 34)

Appendix III-03 (cont.)

Date	Lindane	Aldrin	Heptachlor	Endrin	Dieldrin	Methoxy-chlor	Myrex	Chlordane
3-8-72	0	0	0	0	0	0	0	68.34
4-5-72	0	0	0.53	0	0	0	0	9.67
5-31-72	0	0	1.10	0	0	0	0	33.90
6-29-72	1.05	0	0	0	0	0	0	18.11
9-2-72	0	0	2.65	0	0	0	0	197.69
10-12-72	6.52	0	29.78	0	0	0	0	402.47
11-28-72	5.24	4.97	2.33	15.14	3.20	0	0	111.80
1-12-73	0	0	4.18	0	0	0	0	174.21
Mean	1.60	0.62	5.07	1.89	0.40	0.0	0.0	127.02
Standard Deviation	2.69	1.76	10.09	5.35	1.13	0.0	0.0	131.51

Pesticide Residues of Sediment in Micrograms per Kilogram

TRINITY RIVER AT HIGHWAY 85 (BRIDGE ON U.S. HIGHWAY 85)

Appendix III-03 (cont.)

Date	Organics %	Clay %	Silt %	Sand %	Dry Weight %	DDT	DDE
2-18-72	2.7	19	6	75	74.5	0	0
4-5-72	6.8	35	41	24	68.5	0	2.12
5-31-72	7.2	48	27	25	68.3	0	0.69
9-2-72	8.0	47	8	45	65.4	0	0
1-12-73	8.1	45	31	[illegible]	[illegible]	0	9.0
Mean	6.6	38.8	22.6	38.6	68.6	0.0	2.36
Standard Deviation	2.2	12.2	15.1	22.2	3.5	0.0	3.81

Pesticide Residues of Sediment in Micrograms per Kilogram

TRINITY RIVER AT HIGHWAY 85 (BRIDGE ON U.S. HIGHWAY 85)

Appendix III-03 (cont.)

Date	Lindane	Aldrin	Heptachlor	Endrin	Dieldrin	Methoxy-chlor	Myrex	Chlordane
2-16-72	0	0	0.87	0	0	0	0	54.57
4-5-72	0	0	0.39	0	2.12	0	0	19.71
5-31-72	2.19	0	0.21	0	0	0	0	6.27
9-2-72	0	0	0.32	0	0	0	0	6.78
1-12-73	0	0	2.22	0	0	0	0	161.12
Mean	0.44	0.0	0.80	0.0	0.42	0.0	0.0	49.69
Standard Deviation	o.98	0.0	0.83	0.0	0.95	0.0	0.0	65.32

Pesticide Residues of Sediments in Micrograms per Kilogram

TRINITY RIVER AT CAYUGA, TEXAS (BRIDGE ON U.S. HIGHWAY 287)

Appendix III-03 (cont.)
(-- no sample)

Date	Organics %	Clay %	Silt %	Sand %	Dry Weight %	DDT	D[illegible]E
1-29-72	3.0	21	50	29	70.9	0	0
3-8-72	7.1	35	34	31	66.9	0	2.3[illegible]
4-5-72	6.6	41	20	39	71.9	0	0.8[illegible]
5-31-72	3.5	38	37	25	74.0	0	0
6-29-72	6.4	35	32	33	69.1	0	0.34
10-26-72	5.1	39	26	35	67.8	0	0.99
11-21-72	6.4	--	--	--	66.7	7.34	4.62
12-29-72	4.8	17	14	69	75.0	0	0.37
1-13-73	--	56	28	16	68.4	0.55	0.32
Mean	5.4	35.3	30.1	34.6	70.1	0.88	1.10
Standard Deviation	1.5	12.1	11.1	15.5	3.04	2.43	1.51

Pesticide Residues of Sediments in Micrograms per Kilogram

TRINITY RIVER AT CAYUGA, TEXAS (BRIDGE ON U.S. HIGHWAY 287)

Appendix III-03 (cont.)

Date	Lindane	Aldrin	Heptachlor	Endrin	Dieldrin	Methoxy-chlor	Myrex	Chlordane
1-29-72	0.67	9.58	0	0	0	0	0	1.63
3-8-72	0	1.59	2.22	0	3.60	0	0	82.31
4-5-72	0	0	0.27	0	0	0	0	6.43
5-31-72	0	0	0.29	0	0	0	0	1.38
6-29-72	0	0	0.20	0	0	0	0	26.62
10-26-72	1.20	0	0.65	4.03	0	0	0	34.10
11-21-72	0	0.62	1.42	0	1.85	0	1.52	46.71
12-29-72	0	0	0	0	0	0	0	2.49
1-13-73	3.92	0	0	0	0	0	0	0
Mean	0.64	1.31	0.56	0.45	0.61	0.0	0.17	22.41
Standard Deviation	1.30	3.15	0.77	1.34	1.28	0.0	0.51	28.20

Pesticide Residues of Sediments in Micrograms per Kilogram

TRINITY RIVER AT FAIRFIELD, TEXAS (BRIDGE ON U.S. HIGHWAY 79)

Appendix III-03 (cont.)

Date	Lindane	Aldrin	Heptachlor	Endrin	Dieldrin	Methoxy-chlor	Myrex	Chlordane
1-29-72	3.04	0	0	0	0	0	0	34.17
2-18-72	0	0	0	0	0	0	0	6.33
4-5-72	0	0	0	0	0	0	0	0
5-31-72	0	0	<.20	0	0	0	0	5.11
6-29-72	0	0	<.20	0	0	0	0	26.28
9-2-72	0	0	0	0	0	0	0	16.06
10-19-72	0	0	0	0	0	0	0	2.48
11-21-72	0.93	0	0.58	0	0	0	0	10.48
12-29-72	0	<.20	<.20	0	0	00	0	7.34
1-12-72	0	<.20	<.20	0	0	0	0	12.62
Mean	0.40	<.04	<.14	0.0	0.0	0.0	0.0	12.09
Standard Deviation	0.97	.007	0.18	0.0	0.0	0.0	0.0	10.80

Pesticide Residues of Sediments in Micrograms per Kilogram

TRINITY RIVER AT FAIRFIELD, TEXAS (BRIDGE ON U.S. HIGHWAY 79)

Appendix III-03 (cont.) (-- no sample)

Date	Organics %	Clay %	Silt %	Sand %	Dry Weight %	DDT	DDE
1-29-72	3.5	22	10	68	73.5	0	0.82
2-18-72	1.8	--	--	--	85.2	0	0
4-5-72	9.2	46	30	24	74.4	0	0
5-31-72	5.5	22	23	55	73.8	0	0.58
6-29-72	2.6	12	10	78	83.2	0	0.68
9-2-72	1.5	10	8	82	77.6	0	0.41
10-19-72	1.4	17	14	69	78.4	0	0.27
11-21-72	2.7	19	20	61	88.1	0	0.46
12-29-72	2.9	17	14	69	73.4	0	0.51
1-12-72	2.8	22	17	61	75.4	1.18	1.23
Mean	3.4	20.8	16.2	63	78.3	0.12	0.50
Standard Deviation	2.4	10.4	7.1	16.9	5.4	0.37	0.37

Pesticide Residues of Sediment in Micrograms per Kilogram

TRINITY RIVER AT CROCKETT, TEXAS (BRIDGE ON STATE HIGHWAY 7)

Appendix III-03 (cont.) (-- no sample)

Date	Organics %	Clay %	Silt %	Sand %	Dry Weight %	DDT	DDE
2-18-72	2.2	15	10	75	78.0	0	0.55
4-5-72	5.7	22	16	62	76.6	0	0.45
5-31-72	3.5	21	10	69	79.4	0	0
6-29-72	4.0	28	21	51	75.9	0	1.59
9-2-72	1.4	5	9	86	78.2	0	0
10-21-72	0.7	--	--	--	81.8	1.85	0.22
1-12-73	2.2	--	--	--	76.3	2.85	1.76
Mean	2.8	18.2	13.2	68.6	78.0	0.67	0.65
Standard Deviation	1.7	8.7	5.2	13.2	2.1	1.18	0.73

Pesticide Residues of Sediment in Micrograms per Kilogram

TRINITY RIVER AT CROCKETT, TEXAS (BRIDGE ON STATE HIGHWAY 7)

Appendix III-03 (cont.)

Date	Lindane	Aldrin	Heptachlor	Endrin	Dieldrin	Methoxy-chlor	Myrex	Chlordane
2-18-72	0	0	0	0	0	0	0	6.79
4-5-72	1.03	0	0	0	0	0	0	4.33
5-31-72	<.20	0	0	0	0	0	0	0
6-29-72	<.20	0	0	0	0	0	0	21.95
9-2-72	<.20	0	0	0	0	0	0	1.82
10-21-72	0	0	0.32	0	0	0	1.28	3.71
1-12-73	0.36	0	0	0	0	0	0	29.65
Mean	<.28	0.0	0.05	0.0	0.0	0.0	0.18	9.75
Standard Deviation	0.35	0.0	0.12	0.0	0.0	0.0	0.48	11.38

Pesticide Residues of Sediment in Micrograms per Kilogram

TRINITY RIVER AT MADISONVILLE, TEXAS (BRIDGE ON STATE HIGHWAY 21)

Appendix III-03 (cont.)

Date	Organics %	Clay %	Silt %	Sand %	Dry Weight %	DDT	DDE
2-18-72	1.3	8	9	83	71.1	0	0.52
4-5-72	1.6	13	8	79	74.9	0	0.52
5-31-72	2.0	8	5	87	78.8	0	0.49
6-29-72	2.7	15	10	75	82.4	0.60	0.73
9-2-72	2.3	10	16	74	71.6	0	0.94
10-21-72	1.8	9	4	87	77.9	0	0.45
11-21-72	1.9	13	9.0	78	74.8	0.63	0.90
1-12-73	4.6	27	26	47	68.9	2.97	2.76
Means	2.3	12.9	10.9	76.2	75.0	0.53	0.91
Standard Deviation	1.0	6.3	[illegible]	12.8	4.50	1.03	0.77

Pesticide Residues of Sediment in Micrograms per Kilogram

TRINITY RIVER AT MADISONVILLE, TEXAS (BRIDGE ON STATE HIGHWAY 21)

Appendix III-03 (cont.)

Date	Lindane	Aldrin	Heptachlor	Endrin	Dieldrin	Methoxy-chlor	Myrex	Chlordane
2-18-72	0	0	0	0	0	0	0	5.70
4-5-72	0	0	0	3.00	0	0	0	22.79
5-31-72	0	0	0.20	0	0	0	0	3.10
6-29-72	0	0	0	0	0	0	0	4.20
9-2-72	<.20	0	0	0	0	0	0	104.6
10-21-72	0	0	0	0	0	0	0	2.45
11-21-72	<.20	<.20	<.20	2.49	0	0	0	8.32
1-12-73	0	0	0.63	0	0	0	0	50.05
Mean	<.05	<.02	0.10	0.69	0.0	0.0	0.0	25.15
Standard Deviation	.09	.07	0.22	1.28	0.0	0.0	0.0	35.33

Pesticide Residues of Sediment in Micrograms per Kilogram
TRINITY RIVER AT TRINIDAD, TEXAS (BRIDGE ON STATE HIGHWAY 31)

Appendix III-03 (cont.)

Date	Organics %	Clay %	Silt %	Sand %	Dry Weight %	DDT	DDE
10-26-72	5.0	42	27	31	64.8	0	1.82

TRINITY RIVER AT WALLISVILLE, TEXAS (BRIDGE ON IH-10)

Date	Organics %	Clay %	Silt %	Sand %	Dry Weight %	DDT	DDE
6-21-72	4.9	11	22	67	79.5	0	0

Pesticide Residues of Sediment in Micrograms per Kilogram
TRINITY RIVER AT TRINIDAD, TEXAS (BRIDGE ON STATE HIGHWAY 31)

Appendix III-03 (cont.)

Date	Lindane	Aldrin	Heptachlor	Endrin	Dieldrin	Methoxy-chlor	Myrex	Chlordane
10-26-72	0.70	0	0.40	6.14	0.81	0	0	20.94

TRINITY RIVER AT WALLISVILLE, TEXAS (BRIGE ON IH-10)

Date	Lindane	Aldrin	Heptachlor	Endrin	Dieldrin	Methoxy-chlor	Myrex	Chlordane
6-21-72	0.20	0	0	0	0	0	0	<1.0

Appendix III-04. List of phytoplankton and relative abundance* by stations in the Trinity River from September 1972 to April 1973

STATION	1	2	3	4	5	6	7	8	9	10
Division Chlorophyta										
Actinastrum gracilmum			R		C	R	R			
Actinastrum sp.			R				R			
Ankistrodesmus sp.		O	O		F	O	O	F	F	O
Arthrodesmus incus	O	R	R	R	F	O	O	R	O	O
Chlamydomonas sp.	F		O	O	F	O	O	O	F	O
Chlorella sp.	D	O	D	D	D	D	O	F	O	C
Chlorogonium sp.				R	O	O	R	O	R	R
Chloromonas sp.					O	R				
Closteriopsis sp.		F								
Closterium abruptum										R
Closterium sp.		O	O	R	R		O			
Closterium setaceum										R
Coccomonas sp.			R							
Coelastrum sp.				O	O	O				

Appendix III-04 (cont.)

STATION	1	2	3	4	5	6	7	8	9	10
<u>Crucigenia rectangularis</u>			R							
<u>Crucigenia sp.</u>			C	O	O					
<u>Eudorina sp.</u>				R	R	R	R			
<u>Golenkinia sp.</u>				R						
<u>Gonium sp.</u>				R						
<u>Kirchneriella lunaris</u>				O						
<u>Kirchneriella obesa</u>								F	C	
<u>Kirchneriella sp.</u>					F					
<u>Lagerheimia sp.</u>		O								
<u>Micractinium pusillum</u>	O	F	F	F	O	O	O	F	F	O
<u>Micractinium pusillum</u> var. elegans						O	O			
<u>Micractinium sp.</u>			O	O	F	O	O			
<u>Micrasterias sp.</u>					O					
<u>Pandorina sp.</u>			R	R	O	R				
<u>Pediastrum duplex</u>					O					
<u>Pediasrum sp.</u>				O		O				

Appendix III-04 (cont.)

STATION	1	2	3	4	5	6	7	8	9	10
Polyedriopsis spinulosa					R					
Pseudotetrahedron sp.			R	R	R					
Pteromonas sp.			R	R	R	R				
Scenedesmus abundans					O	O			R	
Scenedesmus acuminatus	O	F	O	O	O	R	R			
Scenedesmus arcuatus			F	O	O		O			
Scenedesmus Bernardii				R	O		R			
Scenedesmus bijuga			O	R	R	R	R			
Scenedesmus denticulatus			R		O					
Scenedesmus dimorphus	F	F	F	F	O	O	R	O	O	R
Scenedesmus incrassatulus							R			
Scenedesmus quadricauda	O	O	A	F	F	O	O	O	O	F
Scenedesmus sp.			R				R			
Spinoclosterium sp.				O		R				R
Staurastrum sp.				R						
Tetradesmus sp.	O		R							

Appendix III-04 (cont.)

STATION	1	2	3	4	5	6	7	8	9	10
Tetraedron arthrodesmiformi					R	R	R			
Tetraedron minimum										R
Tetraedron sp.										O
Tetraedron [illegible]								O	F	
Tetraedron victorieae				R	R	R	R			
Tetrastrum sp.			R							
Volvox sp.										[illegible]
Division Chrysophyta										
Class Bacillariophyceae										
Diploneis smithii	R						C	O	O	F
Eunotia pectinalis					R					
Fragellaria sp.								R		
Cyclotella stelligera										C
Cymbella turgida									O	
Cymbella ventricosa			R	O	O	O	O	O	C	F

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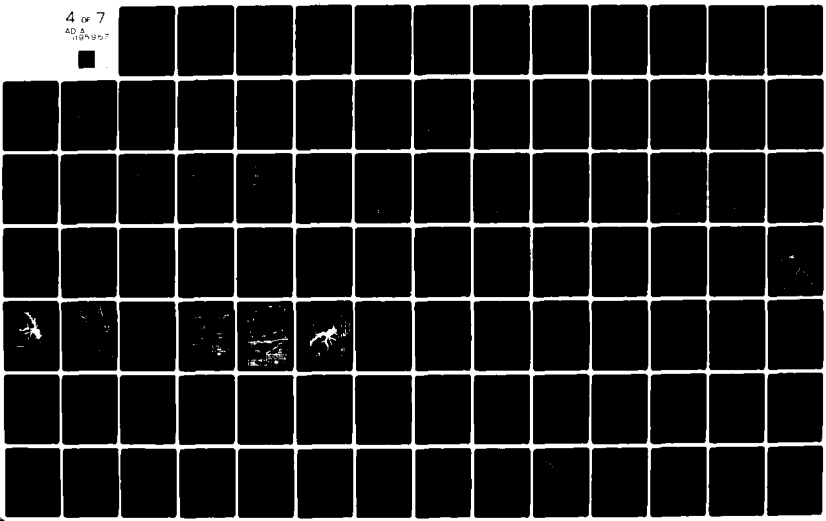


Appendix III-04 (cont.)

STATION	1	2	3	4	5	6	7	8	9	10
<u>Cyclotella</u> <u>glomerata</u>								F	C	A
<u>Cyclotella</u> <u>kutzingiana</u>			R							F
<u>Cyclotella</u> <u>meneghiniana</u>			R	C	O	F	A	F	F	F
<u>Cyclotella</u> <u>sp.</u>									F	
<u>Gomphonema</u> <u>angustatum</u>			O	C	O	R	R		C	
<u>Gomphonema</u> <u>parvulum</u>	O	D	F	O	O	O	O	R	C	R
<u>Melosira</u> <u>abigua</u>						O				
<u>Melosira</u> <u>distans</u>										D
<u>Melosira</u> <u>granulata</u>	R		R	C	[illegible]	F	F	D	D	A
<u>Melosira</u> <u>herzogii</u>					O					
<u>Melosira</u> <u>islandica</u>						R	O			
<u>Melosira</u> <u>italica</u>							R			
<u>Melosira</u> <u>sp.</u>	R		R	C	O	O	O		F	O
<u>Navicula</u> <u>cryptocephala</u>	F	F	F	F	O	O	D	R	C	C
<u>Navicula</u> <u>exigua</u>							O			
<u>Navicula</u> <u>pusilla</u>		O								

Appendix III-04 (cont)

STATION	1	2	3	4	5	6	7	8	9	10
Navicula rhynchocephala	R	O	F	O	O	R	C	C	R	R
Navicula sp.			O	O	O	R	R			
Nitzschia amphibia									C	
Nitzschia acicularis	R	F	A	F	O	R	R			C
Nitzschia kutzingiana							O			
Nitzschia palea	D	F	F	C	O	O	O	O	F	F
Nitzschia vermicularis						O	R			
Pinnularia biceps					O					
Pleurosigma sp.			R			R	C			
Stauroneis sp.									R	
Stephanodiscus astrea							R			
Surirella decipiens							R			
Surirella conifera						R	R	R	R	R
Synedra ulna			R	O	O	O	C	O	O	F

Appendix III-04 (cont.)

STATION	1	2	3	4	5	6	7	8	9	10
Division Chrysophyta										
Class Chrysophyceae										
<u>Synura</u> sp.			R							
Division Cyanophyta										
<u>Chamaesiphon</u> <u>sp</u>.			R	O	F	O	R			
<u>Chroococcus</u> <u>sp</u>.		O					F		R	
<u>Merismopedia</u> <u>sp</u>.								O	R	
<u>Oscillatoria</u> <u>sp</u>.	O	R	R	R	R	R	R			
<u>Phormidium</u> <u>sp</u>.							R			
<u>Rivularia</u> <u>sp</u>.						R				
Division Euglenophyta										
<u>Euglena</u> <u>acus</u>	O	O	F	O	R	R	R		R	
<u>Euglena</u> <u>hemichromata</u>			R							
<u>Euglena</u> <u>oxyuris</u>							R			
<u>Euglena</u> <u>ruba</u>	F				R					
<u>Euglena</u> <u>sp</u>.	R	O	R	R			R			

Appendix III-04 (cont.)

STATION	1	2	3	4	5	6	7	8	9	10
Phacus acuminatus	F		O				R			
Phacus longicauda	R	R	F	O	O	R	R		O	
Phacus oscillans				F						
Phacus tortus			O	F						
Phacus sp.							R			
Division Pyrrhophyta										
Ceratium hirundinella										F
Dinoflagellate						C				

Relative Abundance:

D = Dominant

A = Abundant

F = Frequent

O = Occasional

R = Rare

Appendix III-05. Phytoplankton chlorophyll concentrations in water samples taken from the Trinity River from September 1972 through April 1973 (expressed in mg/m^3)

Ca = Chlorophyll a
Cb = Chlorophyll b
Cc = Chlorophyll c
Cabc = Total Chlorophylls

STATIONS	1	2	3	4	5	6	7	8	9	10
SEPTEMBER										
Ca						11.2	16.6			
Cb						9.8	12.2			
Cc						3.8	12.2			
Cabc						24.8	41.0			
OCTOBER										
Ca	3.3	20.1	30.4	31.1	27.5	23.8	16.8	12.5	7.9	11.4
Cb	6.5	13.6	27.3	22.1	24.2	16.3	10.8	9.3	3.5	7.8
Cc	6.7	28.5	26.8	61.9	28.6	15.0	1.8	3.3	0	0
Cabc	16.5	62.2	84.5	115.1	80.3	55.1	29.4	25.1	11.4	19.2
NOVEMBER										
Ca	.8	4.9	1.9	5.0	5.5	.1	5.0		11.5	27.6
Cb	5.2	0	.2	0	0	6.1	.13		13.2	35.6
Cc	9.3	23.6	1.4	2.2	44.8	14.8	0		12.2	62.2
Cabc	15.3	28.5	3.5	7.2	50.3	21.0	5.1		36.9	125.4
DECEMBER										
Ca	11.5	35.4	8.1				10.9	11.3	18.7	24.6
Cb	13.3	38.3	7.9				12.2	8.2	26.7	25.2
Cc	12.2	64.1	3.7				10.3	0	61.3	69.7
Cabc	37.0	137.8	19.7				33.7	19.5	106.7	119.5
JANUARY										
Ca	5.7	6.7	6.8	7.9	9.2	7.3	3.4	8.8		
Cb	6.6	7.5	7.1	10.3	8.9	9.8	3.3	6.1		
Cc	18.9	28.8	20.9	14.3	11.6	23.7	20.5	22.8		
Cabc	31.2	43.0	34.8	32.5	29.7	40.8	27.2	37.7		

Appendix III-05 (cont.)

STATIONS	1	2	3	4	5	6	7	8	9	10
FEBRUARY										
Ca	18.3	23.0	23.9	21.3	17.2	28.3	12.5	31.1	29.3	29.9
Cb	18.7	22.3	19.4	19.0	17.1	23.6	13.8	35.6	30.6	29.7
Cc	51.0	47.5	52.1	44.6	39.0	82.5	36.4	66.6	56.1	65.0
Cabc	88.0	92.8	95.4	84.9	73.3	134.4	62.7	133.3	116.0	124.6
MARCH										
Ca	24.0	28.8	34.8	28.5	23.5	23.6	22.5	21.9	18.8	20.7
Cb	23.7	25.7	30.6	36.8	25.3	33.8	21.4	20.3	20.8	21.5
Cc	77.2	80.6	77.8	64.4	47.6	46.2	48.7	52.9	49.0	44.2
Cabc	124.9	135.1	143.2	129.7	96.4	103.6	92.6	95.1	88.6	86.4
APRIL										
Ca	13.3	12.8	15.0	20.0		10.9	10.0	11.7	10.6	16.1
Cb	10.6	13.3	13.9	20.6		10.0	8.9	12.2	7.2	13.9
Cc	38.9	37.2	37.8	55.6		26.7	34.4	24.4	26.7	33.9
Cabc	62.8	63.3	66.7	96.2		47.6	53.3	48.3	44.5	63.9

Ca = Chlorophyll a
Cb = Chlorophyll b
Cc = Chlorophyll c
Cabc = Total Chlorophylls

Appendix III-06. List of periphyton diatoms and their relative abundance* by stations in the Trinity River from September 1972 through March 1973

STATIONS	1	2	3	4	5	6	7	8	9	10
Achnanthes exigua						O				
Achnanthes hauckiana								R		
Amphiprora sp.										R
Anomoeneis serians				A	R					
Cyclotella kutzingiana				O		O	F	O		
Cyclotella meneghiniana				R	O	O	O	O		
Cyclotella ocellata								R		
Cyclotella stelligera				R						
Cyclotella striata								R		R
Cymbella affinis									O	
Cymbella prostrata								R		
Cymbella tumida										R

Appendix III-06 (cont.)

STATIONS	1	2	3	4	5	6	7	8	9	10
Cymbella turgida					A	R		R		O
Cymbella ventricosa				R	R	O				
Diploneis interrupta								R		
Diploneis pseudovalis			R							
Diploneis smithii				R		R		F		F
Epithemia sp.										R
Frustulia rhomboides				R	R	R				
Gomphonema acuminatum				R	O	O				O
Gomphonema angustatum			F	F	F	F	O		O	O
Gomphonema olivaceum				F	O	O	O	O	O	O
Gomphonema parvulum	A		D	D	D	D	D	O	F	F
Gyrosigma kutzingii										O
Gyrosigma scalproides					O					
Melosira granulata							F	F	D	F
Melosira herzogii						O				

Appendix III-06 (cont.)

STATIONS	1	2	3	4	5	6	7	8	9	10
Melosira islandica									A	
Navicula biconica				A	O	F				
Navicula cryptocephala			F	O	R	O	F	F	O	
Navicula cuspidata				R						
Navicula elginensis				O	R	R				R
Navicula exigua				R	O	O				
Navicula gastrum				O	O	O				O
Navicula insignita						O				
Navicula laevissima	R									
Navicula laterostrata				F						
Navicula mobiliensis				C	R					
Navicula muralis				O	O					
Navicula pusilla									R	
Navicula pupula									C	
Navicula rhyncocephala				O	F	F				D
Navicula viridula										R

Appendix III-06 (cont.)

STATIONS	1	2	3	4	5	6	7	8	9	10
Nedium iridis								O		
Nitzschia acicularis	O					R		O		
Nitzschia amphibia				O	F	O	O			
Nitzschia filiformis				R	R					
Nitzschia gracilis										R
Nitzschia kutzingiana	O				O		O	O		R
Nitzschia lacunarum				O	F	O		R		
Nitzschia obtusa						O				
Nitzschia lorenziana				R						
Nitzschia palea	D	D	F	A	F	F	O	O	O	F
Nitzschia parvula				O	O	O				O
Nitzschia sigmoidea										O
Nitzschia sublinearis					O	O				
Nitzschia subrostrata						R		C		
Nitzschia thermalis				R		O				
Opephora martyi									R	

Appendix III-06 (cont.)

STATION	1	2	3	4	5	6	7	8	9	10
Pleurosigma delicatulum									O	O
Pleurosigma sp.						O				
Pinnularia biceps				R		O	R			R
Pinnularia microstauron							R			
Pinnularia sudetica										R
Rhopalodia gibberula					R					
Stauroneis acuta							R			
Stauroneis anceps				O						
Stauroneis sp.					R					
Stephanodiscus astrea								R		
Surirella elegans										R
Surirella linearis							O			
Surirella ovalis			R					C	C	O
Surirella ovata								O		
Surirella tenera										R
Synedra acus				O						

Appendix III-06 (cont.)

STATION	1	2	3	4	5	6	7	8	9	10
Synedra rumpens							A			F
Synedra ulna			O	O	R	R	F			O

Relative Abundance:

D = Dominant

A = Abundant

F = Frequent

O = Occasional

R = Rare

Appendix III-07. Benthic organisms collected in the Trinity River from river mile 520 to river mile 10, September 1972 through March 1973

September, 1972

number per 1/25 sq. meter / percent of total organisms

STATION*	6	7	8	9	10
NEMATODA		3/15.0	No organisms present		No organisms present
ANNELIDA					
Oligochaeta					
Tubificidae	18/20.4	3/15.0		20/74.1	
Unidentified				3/11.1	
Hirudinea					
Rhynchobdellida					
Placobdella sp.		2/10.0			
ENDOPROCTA					
Urnatella gracilis Leidy		9/45.0			
ARTHROPODA					
Mandibulata					
Insecta					
Ephemeroptera larvae					
Hexagenia sp.		2/10.0			
Dipteran larvae					
Chironomidae		1/5.0		4/14.8	
MOLLUSCA					
Gastropoda					
Ferrissia sp.	59/67.0				
Others	4/4.5				
Pelecypoda					
Eupera sp.	6/6.8				
Others	1/1.1				
TOTAL ORGANISMS	88	20		27	
DIVERSITY INDEX	1.3953	2.2200		1.0810	

* No samples were taken from the other stations during this month.

Appendix III-07 (cont.)

October, 1972

number per 1/25 sq. meter / percent of total organisms

STATION	1	2	3	4
NEMATODA		1/0.37		
ANNELIDA				
Oligochaeta				
Tubificidae	325/85.5	165/61.8	2600/93.9	18/5.6
Unidentified				
Hirudinea				
Arhynchobdella				
ENDOPROCTA				
Urnatella gracilis **Leidy**				
ECTOPROCTA				
ARTHROPODA				
Mandibulata				
Insecta				
Ephemeroptera larvae				
Hexagenia **sp.**				
Trichoptera larvae				
Diptera				
Chironomidae				
larvae	12/3.2	32/12.0	148/5.4	304/94.4
pupae		12/4.5		
Ceratopogonidae			20/0.7	
MOLLUSCA				
Gastropoda				
Ferrissia **sp.**	42/10.8	57/21.3		
Others				
Pelecypoda				
Eupera **sp.**	1/0.3			
Others				
TOTAL ORGANISMS	380	267	2768	322
DIVERSITY INDEX	0.9446	1.8310	0.3622	0.3110

Appendix III-07 (cont.)
October, 1972

number per 1/25 sq. meter / percent total organisms

5	6	7	8	9	10
			14/29.2		1/33.3
58/65.9	45/70.3	47/47.9	14/29.2	43/67.2	
				3/4.7	
1/1.1					
	3/4.7	27/27.6			1/33.3
3/3.4					
			11/22.9	15/23.4	
	3/4.7				
25/28.4	4/6.2	15/15.3	9/18.8		
				3/4.7	
	9/14.1				
1/1.1		3/3.1			
		1/1.0			
		2/2.0			1/33.3
88	64	98	48	64	3
1.2252	1.4192	1.9060	1.9760	1.2900	1.5850

Appendix III-07 (cont.)

November, 1972

number per 1/25 sq. meter / percent total organisms

STATION	1	2	3	4
NEMATODA				
ANNELIDA				
Oligochaeta				
Tubificidae	334/94.9	**Presence of raw sewage prevented examination**	6700/98.9	2/2.4
Polychaeta				
Hirudinia				
Rhynchodbdellida				
***Placobdella* sp.**				5/5.9
ARTHROPODA				
Mandibulata				
Crustacea				
Malacostraca				
Amphipoda				
Insecta				
Trichoptera larvae				
Coleoptera larvae	1/1.3			
Diptera				
Chironomidae larvae	7/2.00		69/1.0	68/80.0
Ceratopogonidae larvae	6/1.0		2/0.02	9/10.6
Culicidae larvae				
***Chaoborus* sp.**			1/0.01	
MOLLUSCA				
Gastropoda				
***Ferrissia* sp.**				
Others	4/1.1			1/1.2
TOTAL ORGANISMS	352		6772	85
DIVERSITY INDEX	0.3910		0.8802	1.0437

-- indicates no sample taken

Appendix III-07 (cont)
November, 1972

number per 1/25 sq. meter / total number of organisms

5	6	7	8	9	10
		---	---	1/25.0	
1/3.9	1/20.0			2/50.0	1/2.5
					1/2.5
					21/52.5
	3/60.0				
25/96.2	1/20.0				17.42.5
				1/25.0	
26	5			4	40
0.2352	1.3710			1.5000	1.2788

Appendix III-07 (cont.)
December, 1972

number per 1/25 sq. meter / total number of organisms

STATION	4	7	8	9	10
NEMATODA				2/6.7	
ANNELIDA					
Oligochaeta					
Tubificidae	500/89.4	15/46.9		4/13.3	1/7.1
Polychaeta					1/7.1
Hirudinea					
Piscicolidae	2/0.4				
Unidentified	4/0.7				
ENDOPROCTA					
<u>Urnatella</u> <u>gracilis</u> Leidy		4/12.5	2/2.0		
ARTHROPODA					
Mandidbulata					
Crustacea					
Malacostraca					
Amphipoda					1/7.1
Decapoda					
<u>Procambarus</u> sp.			1/1.0		
Insecta					
Ephemeroptera larvae					
<u>Hexagenia</u> sp.			24/23.5		
Odonata larvae					
Zygoptera			1/1.0		
Hemiptera					
Corixidae			2/2.0		
Trichoptera larvae			10/9.8	5/16.7	
Lepidoptera larvae				1/3.3	
Coleoptera					
<u>Berosus</u> sp. (?)			1/1.0		
Diptera larvae					
Tipulidae			1/0.98		
Chironomidae	1/0.2	1/3.1	39/38.2	16/53.3	11/78.6
Ceratopogonidae	8/1.4		8/7.8	1/3.3	
Culicidae					
<u>Chaoborus</u> sp.		2/6.2			

Appendix III-07 (cont.)

December, 1972
number per 1/25 sq. meter / total number of organisms

STATION	4	7	8	9	10
MOLLUSCA					
Gastropoda					
Ferrissia sp.	5/0.9				
Others	39/7.9	1/3.1	1/1.0		
Pelecypoda		9/28.1			
Amblema sp.					
Lampsilis sp.					
TOTAL ORGANISMS	559	32	102	30	14
DIVERSITY INDEX	0.7675	1.9646	2.2530	2.1736	1.0892

* No samples were taken from the other stations during this month

Appendix III-07 (cont.)
January, 1973

number per 1/25 sq. meter / total number of organisms

STATION	1	2	3	4
NEMATODA				1/20.0
ANNELIDA				
Oligochaeta				
Tubificidae	220/91.3	37/92.5	1200/100.0	1/20.0
Hirudinea				
ENDOPROCTA				
Urnatella gradilis Leidy				
ARTHROPODA				
Mandibulata				
Crustacea				
Malacostraca				
Amphipoda				
Decapoda				
Paleomonaetes sp.				
Insecta				
Ephemeroptera larvae				
Hexagenia sp.				
Diptera larvae				
Chironomidae				
Ceratopogonidae				
MOLLUSCA				
Gastropoda				
Ferrissia sp.				
Others	25/10.2	3/7.5		3/80.0
Pelecypoda				
Eupera sp.				
Others				
Amblema sp.				
Lampsilis sp.				
Proptera sp.				
Ligumia sp.				
TOTAL ORGANISMS	245	40	1200	5
DIVERSITY INDEX	0.4754	0.4532	0	1.3710

Appendix III-07 (cont.)

January, 1973

number per 1/25 sq. meter / total number of organisms

5	6	7	8	9	10
				1/12.5	1/2.5
	9/64.3	1/35.0		5/62.5	14/35.0
1/33.3					
		1/25.0	2/6.9		
	2/14.3		2/6.9		
		1/25.0			
					1/2.5
1/33.3	3/21.4		1/3.5	1/12.5	21/52.5
			8/27.6		
		1.25.0	1/3.5		
1/33.3			5/17.2	1/12.5	
			2/6.9		
			8/27.6		
3	14	4	29	8	40
1.5850	1.2870	2.0000	2.5956	1.5488	2.2129

Appendix III-07 (cont.)

February, 1973

number per 1/25 sq. meter / total number of organisms

STATION	1	2	3	4
NEMATODA				----
ANNELIDA				
Oligochaeta				
Tubificidae	1000/97.6	45/88.2	109/98.2	
Polychaeta				
ARTHROPODA				
Mandibulata				
Crustacea				
Malacostraca				
Amphipoda				
Decapoda				
Insecta				
Ephemeroptera larvae				
Hexagenia sp.				
Odonata larvae				
Anisoptera-*Gomphus*				
Trichoptera larvae				
Diptera				
Chironomidae				
larvae	1/1.0		1/0.9	
pupae		1/2.0	1/0.9	
Ceratopogonidae larvae	15/1.5			
Culicidae larvae				
Chaoborus sp.				
MOLLUSCA				
Gastropoda				
Ferrissia sp.	9/0.9	5/9.8		
Others				
Pelecypoda				
Eupera sp.				
Others				
Amblema spp.				
TOTAL ORGANISMS	1025	51	111	
DIVERSITY INDEX	0.2017	0.6698	0.2205	

----indicates no sample taken

Appendix III-07 (cont.)

number per 1/25 sq. meter / total number of organisms

5	6	7	8	9	10
			No Organisms Present	7/17.5	
38/55.1	20/35.1	7/41.2		1/2.5	1/3.6
					3/10.7
	1/1.8				3/10.7
	1/1.8				
				2/5.0	10/35.7
	1/1.8				
1/1.4	8/14.0	1/5.9		4/10.0	1/3.6
1/1.4	21/36.8			18/45.0	6/21.4
9/13.0	3/5.3			7/17.5	3/10.7
1/1.4					
1/1.4		4/23.5			
16/23.2		3/17.6			
1/1.4					
	2/11.8				
69	57	17		40	28
2.2536	2.1937	2.0636		2.2129	2.5576

Appendix III-07 (cont.)
March, 1973

number per 1/25 sq. meter / total number of organisms

STATION	1	2	3
ANNELIDA	648/93.9	6/66.7	109/98.2
Oligochaeta			
Tubificidae			
ENDOPROCTA			
Urnatella gracilis Leidy			
ECTOPROCTA			
ARTHROPODA			
Mandibulata			
Insecta			
Diptera			
Chironomidae			
larvae			1/0.9
pupae			1/0.9
Ceratopogonidae larvae	35/5.0		
Culicidae larvae			
Chaoborus sp.			
MOLLUSCA			
Gastropoda			
Ferrissia sp.	7/1.0	2/22.2	
Other	1/0.1	1/11.1	
Pelecypoda			
Proptera sp.			
Fusconaria sp. or			
Obovaria sp.			
Lampsilis spp.			
TOTAL ORGANISMS	701	9	111
DIVERSITY INDEX	0.3901	1.2244	0.2205

----indicates no sample taken

Appendix III-07 (cont.)

March, 1973

number per 1/25 sq. meter / total number of organisms

	4	5	6	7	8	9	10
	103/89.6	11/55.0	18/51.4	2/16.7	----	----	121/96.03
				2/16.7			
				1/8.4			
		6/30.0	6/17.1	3/25.0			1/0.8
		2/10.0	1/2.9	1/8.3			
			1/2.9				4/3.2
				1/8.3			
				1/8.3			
	2/1.7	1/5.0		1/8.3			
	10/8.7		9/25.7				
	115	20	35	12			126
	0.5504	1.5438	1.7265	2.8554			0.2695

Appendix III-08. Zooplankton organisms collected in the Trinity River from river mile 520 to river mile 10, September 1972 through March 1973

September, 1972 — number per 5-minute plankton tow/ percent of total organisms

STATION*	6	7	8
PROTOZOA			
Sarcomastigophora			
Sarcodina			
Rhizopodea			
Lobosia			
Arcellinida			
Arcella-like tests	930/0.4	130/0.5	144/1.8
Difflugia-like tests	7998/3.4	1170/4.8	288/3.6
Ciliophora			
Ciliatea			
Peritrichia			
Peritrichida		39/0.2	
ROTIFERA			
Brachionidae	223293/93.8	2535/10.3	1728/21.4
Keratella-type	70/0.03	2470/10.0	
Others			96/1.2
NEMATODA	93/0.04		
ENDOPROCTA			
Urnatella gracilis Leidy		1/0.004	
ARTHOPODA			
Mandibulata			
Arachnida			
Hydracarina			48/0.6
Crustacea			
Branchiopoda			
Cladocera	29/0.01		384/4.8
Ephippia	465/0.20	20/0.08	336/4.2
Ostracoda	3751/1.6		48/0.6
Copepoda	651/0.3	390/1.6	816/10.1
Insecta			
Collembola	29/0.01		
Dipteran larvae	465/0.2	20/0.08	288/3.6
TOTAL ORGANISMS	237960	24563	8064
DIVERSITY INDEX ($\bar{d}$)	0.4505	2.1090	1.8522

* No samples were taken from the other stations during this month

Appendix III-08 (cont.)
October, 1972

number per 5-minute plankton tow/percent of total organisms			
STATION	1	2	3
PROTOZOA			
Sarcomastigophora			
Sarcodina			
Rhizopodea			
Lobosia			
Arcellinida			
Arcella-like tests	2144/71.7	16016/55.4	74/10.6
Difflugia-like tests			
Ciliophora			
Ciliatea			
Peritrichia			
Peritrichida	469/15.7	5368/18.6	1776/25.4
Other ciliates			
ROTIFERA			
Brachionidae	22/0.7	2000/6.9	814/11.7
Keratella-type			25/0.4
Others		880/3.0	
NEMATODA		440/1.5	25/0.4
ANNELIDA			
Oligochaeta			
Tubificidae			
ARTHROPODA			
Mandibulata			
Arachnida			
Hydracarina			
Crustacea			
Branchiopoda			
Cladocera		88/0.3	3182/45.6
Ephippia			25/0.4
Ostracoda	67/2.2	44/0.2	74/1.1
Copepoda	134/4.5	880/3.0	25/0.4
Nauplii	67/2.2	2684/9.3	
Insecta	67/2.2		148/2.1
Collembola			
Ephemeroptera larvae			
Corixidae			
Dipteran larvae	22/0.7	396/1.4	370/5.3
pupae		8/0.03	296/4.2
Hemiptera			148/2.1
TOTAL ORGANISMS	2992	28892	6982
DIVERSITY INDEX	1.3750	1.9353	2.1648

Appendix III-08 (cont.)

October, 1972

number per 5-minute plankton tow/percent of total organisms

STATION	4	5	6
PROTOZOA			
Sarcomastigophora			
Sarcodina			
Rhizopodea			
Lobosia			
Arcellinida			
Arcella-like tests	126/35.3	96/0.8	346/0.1
Difflugia-like tests		288/2.4	2436/0.5
Ciliophora			
Ciliatea			
Peritrichia			
Peritrichida			
Other ciliates			
ROTIFERA			
Brachionidae	420/11.8	3648/31.2	478848/98.7
Keratella- type			348/0.1
Others	1092/30.6	1392/11.8	
NEMATODA			
ANNELIDA			
Oligochaeta			
Tubificidae			
ARTHROPODA			
Mandibulata			
Arachnida			
Hydracarina		14/0.1	
Crustacea			
Branchiopoda			
Cladocera	96/0.8		
Ephippia	13/0.4		116/0.02
Ostracoda	882/24.7	5472/46.2	1044/1.6
Copepoda	42/1.2	288/2.4	1972/0.4
Nauplii	13/0.4	144/0.1	116/0.02
Insecta			
Collembola			
Ephemeroptera larvae			
Corixidae		2/0.02	
Dipteran larvae	966/27.1	384/3.2	116/0.02
pupae			
Hemiptera	13/0.4	14/0.1	
TOTAL ORGANISMS	3567	11840	484996
DIVERSITY INDEX	2.1037	2.0060	0.1301

Appendix III-08 (cont.) October, 1972

number per 5-minute plankton tow/percent of total organisms

STATION	7	8
PROTOZOA		
Sarcomastigophora		
Sarcodina		
Rhizopodea		
Lobosia		
Arcellinida		
Arcella-like tests		138/0.9
Difflugia-like tests	3555/17.6	275/1.7
Ciliophora		
Ciliatea		
Peritrichia		
Peritrichida		55/0.4
Other ciliates		
ROTIFERA		
Brachionidae	5985/29.6	1925/12.0
Keratella-type	2970/14.7	110/0.7
Others		3190/20.0
NEMATODA		
ANNELIDA		
Oligochaeta		
Tubificidae		
ARTHROPODA		
Mandibulata		
Arachnida		
Hydracarina	14/0.1	
Crustacea		
Branchiopoda		
Cladocera	135/0.7	935/5.8
Ephippia	135/0.7	28/0.2
Ostracoda	4230/21.0	632/4.0
Copepoda	3150/15.6	1568/9.8
Nauplii	14/0.1	6930/43.4
Insecta		
Collembola		
Ephemeroptera larvae		6/0.04
Corixidae		
Dipteran larvae		192/1.2
pupae		
Hemiptera		
TOTAL ORGANISMS	20188	15984
DIVERSITY INDEX	2.3500	2.0633

Appendix III-08 (cont.) October, 1972

number per 5-minute plankton tow/percent of total organisms

STATION	9	10
PROTOZOA		
Sarcomastigophora		
Sarcodina		
Rhizopodea		
Lobosia		
Arcellinida		
Arcella-like tests	224/19.3	343/0.05
Difflugia-like tests	224/19.3	
Ciliophora		
Ciliatea		
Peritrichia		
Peritrichida		15/0.8
Other ciliates		
ROTIFERA		
Brachionidae	56/0.5	294/16.1
Keratella-type	17/1.5	
Others		254/13.9
NEMATODA		
ANNELIDA		
Oligochaeta		
Tubificidae	17/0.2	
ARTHROPODA		
Mandibulata		
Arachnida		
Hydracarina		
Crustacea		
Branchiopoda		
Cladocera	56/0.5	
Ephippia	168/14.5	
Ostracoda	168/14.5	49/2.7
Copepoda	17/1.5	147/8.0
Nauplii		735/40.2
Insecta		
Collembola		
Ephemeroptera larvae		
Corixidae		
Dipteran larvae	112/9.65	
pupae		
Hemiptera		
TOTAL ORGANISMS	1161	1827
DIVERSITY INDEX	2.5816	1.1977

Appendix III-08 (cont.)
November, 1972

number per 5-minute plankton tow/percent of total organisms

STATION	1	2	3
PROTOZOA			
Sarcomastigophora			
Sarcodina			
Rhizopodea			
Lobosia			
Arcellinida			
Arcella-like tests	1856/30.0	52/7.1	220/5.5
Difflugia-like tests			
Ciliophora			
Ciliatea			
Peritrichia			
Peritrichida	191/3.1	52/7.1	1650/41.1
ROTIFERA			
Brachionidae	174/2.8		55/1.4
Keratella-type	174/2.8		110/2.7
Others	2552/41.3		550/13.7
NEMATODA		578/78.8	660/16.4
ANNELIDA			
Oligochaeta			
Tubificidae	116/18.8		
ARTHROPODA			
Mandibulata			
Arachnida			
Hydracarina	17/0.3		
Crustacea			
Branchiopoda			
Cladocera	116/1.9		28/7.0
Ephippia			38/0.6
Ostracoda			220/5.5
Copepoda	696/11.3	52/7.1	330/8.2
Nauplii	290/4.7		165/4.1
Insecta			
Dipteran larvae			28/0.7
TOTAL ORGANISMS	6182	734	4016
DIVERSITY INDEX	2.1541	1.0831	2.5064

Appendix III-08 ,cont.) November, 1972

number per 5-minute plankton tow/percent of total organisms

4	5	6	7	8	9	10
1118/18.2	627/1.4	195/2.9			300/6.8	440/4.4
220/3.6	342/7.7	455/6.8			200/4.5	1202/12.0
228/8.0	171/3.9	130/1.9				
642/10.5	171/3.9	520/7.7			600/13.6	2347/23.5
220/3.6	171/3.9	1950/28.9			1100/25.0	1349/13.5
220/3.6	570/12.9	1690/25.1			300/6.8	264/2.6
	57/1.3	46/0.7			100/2.3	
16/0.3						
110/1.8		20/0.3			300/6.8	1291/12.9
38/0.6	17/0.4	65/1.0			100/2.3	53/0.5
	513/11.6	65/1.0			100/2.3	53/0.5
3098/50.5	1539/34.8	1170/17.4			700/15.9	2493/24.9
385/6.3	114/2.6	65/1.0			400/9.1	381/3.8
57/2.0	114/2.6	46/1.0			200/4.5	
6138	4423	6742			4400	9996
1.9834	2.7493	2.4496			2.8884	2.5939

Appendix III-08 (cont.)

January, 1973

number per 5-minute plankton tow/percent of total organisms

STATION	1	2	3	4	5
PROTOZOA					
Sarcomastigophora					
Sarcodina					
Rhizopodea					
Lobosia					
Arcellinida					
Arcella-like tests	2144/71.7		21/5.4	366/24.6	164/21.3
Difflugia-like tests					
Ciliophora					
Ciliatea					
Peritrichia					
Peritrichida	4422/47.1		138/35.7	12/0.8	
Other ciliates					
ROTIFERA					
Brachionidae	20/0.2	34/15.5	138/35.7	183/12.3	12/1.6
Keratella-type			21/5.4	183/12.3	205/26.6
Others		56/25.6		244/16.4	246/31.9
NEMATODA		56/25.6			12/1.6
ARTHROPODA					
Mandibulata					
Crustacea					
Branchiopoda					
Cladocera	20/0.2		28/7.0	12/0.8	41/5.3
Ephippia					
Ostracoda					25/3.2
Copepoda	40/0.4	17/7.8		366/24.6	41/5.3
Insecta	66/0.7		69/17.8	122/8.2	25/3.2
Dipteran larvae		56/25.6			
TOTAL ORGANISMS	9386	219	387	1489	771
DIVERSITY INDEX	1.1163	2.2127	1.9607	2.3088	2.3850

Appendix III-08 (cont.)

December, 1972

number per 5-minute plankton tow/percent of total organisms

STATION*	4	7	8	9	10
PROTOZOA					
Sarcomastigophora					
Sarcodina					
Rhizopodea					
Lobosia					
Arcella-like tests	456/15.9	46/3.0	162/7.3	18/2.5	134/1.1
Difflugia-like tests		14/0.9	108/4.9	244/34.0	9782/83.0
Ciliophora					
Ciliatea					
Peritrichia					
Peritrichida	228/8.0				
ROTIFERA					
Brachionidae	171/6.0	46/3.0	54/2.4		201/1.7
Keratella-type	114/4.0	506/33.0	162/7.3		737/6.2
Others	604/21.1	92/6.0	162/7.3	61/8.5	201/1.7
NEMATODA				18/2.5	
ARTHROPODA					
Mandibulata					
Crustacea					
Branchiopoda					
Cladocera	34/1.2	46/3.0	270/12.2	61/8.5	201/1.7
Ephippia			216/9.8	181/25.2	67/0.6
Ostracoda	171/6.0	460/30.0	108/4.9	18/2.5	
Copepoda	912/31.9	322/21.0	864/39.0	61/8.5	201/1.7
Nauplii	114/4.0		54/2.4	37/5.2	201/1.7
Insecta					
Dipteran larvae	57/2.0		54/2.4	18/2.5	
TOTAL ORGANISMS	2861	1532	2214	717	11792
DIVERSITY INDEX	2.5771	2.2832	2.5214	2.2868	1.0376

* Other station were not sampled this month.

Appendix III-08 (cont.)

January, 1973

number per 5-minute plankton tow/percent of total organisms

STATION	6	7	8	9	10
PROTOZOA					
Sarcomastigophora					
Sarcodina					
Rhizopodea					
Lobosia					
Arcella-like tests	208/24.2	324/15.9		47/8.8	
Difflugia-like tests	16/1.9	49/2.4	22/15.8	363/67.7	134/16.0
Ciliophora					
Ciliatea					
Peritrichia	31/0.4				
Peritrichida					
Other ciliates					
ROTIFERA					
Brachionidae					
Keratella-type	208/24.2	243/12.0		24/4.5	20/2.4
Others	104/12.1	81/4.0			
NEMATODA		49/2.4			
ARTHROPODA					
Mandibulata					
Crustacea					
Branchiopoda					
Cladocera	31/3.6	486/23.9	44/31.6	79/14.7	20/2.4
Ephippia		49/2.4	73/52.5	47/8.8	40/4.8
Ostracoda		162/8.0	22/15.8		
Copepoda	52/6.1	567/27.9		24/3.9	20/2.4
Insecta	156/18.2	24/1.2			134/16.0
Dipteran larvae					
TOTAL ORGANISMS	858	2034	139	536	837
DIVERSITY INDEX	2.3092	2.5482	1.0511	1.5238	1.2738

Appendix III-08 (cont.)

February, 1973

number per 5-minute plankton tow/percent of total organisms

STATION	1	2	3	4	5
PROTOZOA				--	
Sarcomastigophora					
Sarcodina					
Rhizopodea					
Lobosia					
Arcellinida					
Arcella-like tests	30/0.7	1500/17.0	1312/27.9	--	814/8.4
Difflugia-like tests					22/0.2
Ciliophora					
Ciliatea					
Peritrichia					
Peritrichida	1400/34.5	1500/17.0	246/5.2	--	2812/29.1
ROTIFERA					
Brachionidae	100/2.5		1394/30.0	--	2442/25.3
Keratella-type	300/7.4	3500/39.6	574/12.2		1554/16.1
Others	1400/34.5				22/0.2
NEMATODA		1000/11.3	246/5.2	--	888/9.2
ARTHROPODA					
Mandibulata					
Arachnida					
Hydracarina	200/4.9	165/1.87			
Crustacea					
Branchiopoda					
Cladocera	200/4.9		82/1.7	--	222/2.3
Ephippia					
Ostracoda					
Copepoda	200/4.9	500/5.7	656/14.0	--	[illegible]
Nauplii	200/4.9	165/1.9	82/1.7		296/3.1
Insecta					
Dipteran larvae	30/0.7	500/5.7	82/1.7	--	
TOTAL ORGANISMS	4060	8832	4699		9664
DIVERSITY INDEX	2.3306	2.3793	2.4734		2.5622

Appendix III-08 (cont.)

February, 1973

number per 5-minute plankton tow/percent of total organisms

STATION	6	7	8	9	10
PROTOZOA					
Sarcomastigophora					
Sarcodina					
Rhizopodea					
Lobosia					
Arcellinida					
Arcella-like tests	560/2.9	623/3.2	17/0.3	47/8.8	64/0.2
Difflugia-like tests	400/2.0	89/0.4	348/5.3	119/3.8	576/1.9
Ciliophora					
Ciliatea					
Peritrichia					
Peritrichida	4533/23.1	4509/22.9			19/0.1
ROTIFERA					
Brachionidae	2347/12.0	2344/12.0	1991/30.4	595/18.8	4331/14.2
Keratella-type	5547/28.3	5103/25.9	3364/51.4	1666/52.6	10624/34.9
Others	160/0.8	89/0.4			128/0.4
NEMATODA	240/1.2	267/1.4			
ARTHROPODA					
Mandibulata					
Arachnida					
Hydracarina	48/0.2	27/0.1	17/0.3		
Crustacea					
Branchiopoda					
Cladocera	3040/15.5	2996/15.2	58/0.9	238/7.5	4949/16.2
Ephippia	80/0.4	27/0.1	35/0.5		64/0.2
Ostracoda	24/0.1		17/0.3	36/1.1	
Copepoda	2000/10.2	3174/16.1	638/9.8	119/3.8	8064/26.5
Nauplii	560/2.9	445/2.3	58/0.9	357/11.3	1600/5.2
Insecta					
Dipteran larvae	24/0.1				19/0.1
TOTAL ORGANISMS	19587	19720	6543	3166	30457
DIVERSITY INDEX	2.6174	2.5582	1.7389	1.9571	1.8321

Appendix III-08 (cont.)

March, 1973

number per 5-minute plankton tow/percent of total organisms

STATION	1	2	3	4	5
PROTOZOA					
Sarcomastigophora					
Sarcodina					
Rhizopodea					
Lobosia					
Arcellinida					
Arcella-like tests	144/2.7	246/8.0	46/0.9	273/2.5	146/1.2
Difflugia-like tests				91/0.8	365/3.1
Ciliophora					
Ciliatea					
Peritrichia					
Peritrichida	792/15.1	984/32.2	2128/39.7	1092/9.9	803/6.8
ROTIFERA					
Brachionidae	144/2.7		2122/39.6	8554/77.5	8760/74.8
Keratella-type	288/5.5	410/13.4	76/1.4	273/2.5	365/3.1
Others	792/15.1	246/8.0			44/0.4
NEMATODA	2088/39.8	574/18.8	380/7.1	27/0.2	22/0.2
ARTHROPODA					
Mandibulata					
Arachnida					
Hydracarina	1/0.02			91/0.8	22/0.2
Crustacea					
Branchiopoda					
Cladocera	22/0.4	82/2.7	76/1.4	182/1.6	146/1.2
Ephippia				91/0.8	22/0.2
Copepoda	360/6.9	164/5.4	380/7.1	364/3.3	803/6.8
Nauplii	576/11.0	164/5.4	152/2.8		219/1.9
Insecta					
Collembola	22/0.4				
Dipteran larvae		164/5.4			
TOTAL ORGANISMS	5251	3059	5360	11038	11717
DIVERSITY INDEX	2.4117	2.7211	1.8929	1.3039	1.4284

Appendix III-08 (cont.)

March, 1973

number per 5-minute plankton tow/percent of total organisms

STATION	6	7	8	9	10
PROTOZOA			No samples taken this month		
Sarcomastigophora					
Sarcodina					
Rhizopodea					
Lobosia					
Arcellinida					
Arcella-like tests	186/3.4	138/10.0			33/0.8
Difflugia-like tests	279/5.1	69/5.0		47/3.4	300/7.3
Ciliophora					
Ciliatea					
Pertrichia					
Peritrichida	2604/47.72				
ROTIFERA					
Brachionidae	1395/25.6	414/30.2		23/1.6	300/7.3
Keratella-type	279/5.1	138/10.0		468/33.7	1300/31.7
Others		21/1.5			
NEMATODA	31/0.6	21/1.5			33/0.8
ARTHROPODA					
Mandibulata					
Arachnida					
Hydracarina	31/0.6	41/3.0			
Crustacea					
Branchiopoda					
Cladocera	279/5.1	207/15.1		47/3.4	300/7.3
Ephippia	80/0.4	41/3.0		23/1.7	100/2.4
Copepoda	372/6.8	276/20.1		546/39.3	1000/24.4
Nauplii				243/16.9	700/17.1
Insecta					
Collembola		6/0.4			
Dipteran larvae					33/0.8
TOTAL ORGANISMS	5456	1373		1388	4099
DIVERSITY INDEX	2.1855	2.6935		1.4768	2.0998

Appendix III-09. Multiple tube fermentation data

Station	October	November	December	January	February	March	April
1	24,000	>240,000	46,000	110,000	9,300 0	0	400
2	24,000	>240,000	>240,000	>240,000	>240,000 240,000	>240,000	>240,000
3	>240,000	110,000 >240,000	>240,000	>240,000	>240,000 110,000	>240,000	110,000
4	4,300 9,300	110,000 2,300	110,000	>240,000 240,000	>240,000 900	1,500	4,300
5	4,300 24,000 110,000 >240,000	46,000	110,000	24,000 24,000	110,000	9,300	4,300
6	46,000 24,000 24,000 4,300 46,000	46,000	110,000	46,000	15,000	9,300	1,500
7	4,300 4,300 21,000 4,300 46,000	24,000	110,000	7,500	4,300	>240,000	700

Appendix III-09 (cont.)

Station	October	November	December	January	February	March	April
8	400 400	900	2,300	9,300	0	0	0
9	9,300 4,300	4,300	9,300	15,000	0	0	0
10	24,000 1,100	2,300	900	4,300	0	0	0

Appendix III-09 (cont.)

TOTAL COLIFORM ANALYSIS

Station	October	November	December	January	February	March	April
1	35,800	79,400	198,000	174,000	100 0	100	700
2	33,800	83,800	2,322,000	2,220,000	3,230,000 580,000	1,000	220,000
3	44,400	66,400	138,000	163,000	530,000 48,000	56,000	68,000
4	22,800	62,600 13,000	115,000	160,000 86,000	79,000 20,000	2,000	7,300
5	13,630 180,000 433,400	52,000	84,000	92,000 63,000	20,000 317,000	2,000	5,900
6	10,600 8,250 13,330 51,000	149,000	144,000	91,000	27,000	7,400	4,200
7	12,000 14,500 333,000 27,000	195,000	87,000	56,000	24,000 6,000	220,000	300

Appendix III-09 (cont.)

Station	October	November	December	January	February	March	April
8	0	1,600	3,000	5,100 2,500	0	0	0
9	0	7,000	6,900	5,000	0	0	0
10	0	7,100	5,400	4,300	0	0	0

Appendix III-09 (cont.)

FECAL COLIFORM ANALYSIS

Station	October	November	December	January	February	March	April
1	21,400	63,460	157,000	129,300	8 0	0	500
2	19,260	75,000	1,880,000	1,836,000	2,153,000 360,000	700	130,000
3	34,000	56,600	104,000	131,000	160,000 1,000	47,000	44,000
4	5,200	46,800 4,000	101,000	103,000 68,000	62,000 0	3,000	4,000
5	8,430 76,660 90,000	19,000	38,000	62,000 22,000	22,000	3,000	2,700
6	9,000 77,000 90,000 47,000	64,000	101,000	68,000	13,000	6,300	2,000
7	7,900 5,930 150,000 23,000	149,000	60,000	35,000	8,000	70,000	1,000
8	0	1,100	1,800	3,400 1,600	0	0	0

Appendix III-09 (cont.)

Station	October	November	December	January	February	March	April
9	0	3,900	4,000	2,800	0	0	0
10	0	5,700	1,100	1,700	0	0	0

Appendix III-09 (cont.)

FECAL STREPTOCOCCUS ANALYSIS

Station	October	November	December	January	February	March	April
1	2,300	16, 00	3,900	13,900	100	0	0
2	3,700	19,100	173,000	102,000	134,000 82,000	200	27,000
3	9,800	8,300	4,400	5,100	7,000 10,000	2,200	4,100
4	900	11,800 2,000	6,000	5,800 3,700	2,420 0	100	700
5	2,000 18,670 15,900	2,600	6,100	12,800 2,500	100	900	800
6	1,300 8,000 8,000 9,600	5,100	4,500	1,600	0	3,500	500
7	7,300 2,370 14,670 3,500	14,800	3,300	3,200	0	3,800	100

The values above refer to fecal streptococcus per 100 ml.

Appendix III-09 (cont.)

Station	October	November	December	January	February	March	April
8	0	0	1,100	1,500 800	0	0	0
9	0	0	1,600	1,500	0	0	0
10	0	0	600	600	0	0	0

RATIO OF FECAL COLIFORM AND FECAL STREPTOCOCCUS

Appendix III-09 (cont.)

Station	October	November	December	January	February	March	April
1	9.504	3.966	40.256	9.302	0.000	0.000	0.000
2	5.205	3.926	10.087	18.000	16.067 4.390	3.500	4.814
3	3.469	6.819	23.636	25.686	22.857 .100	21.363	10.730
4	5.777	3.966 2.000	16.833	17.758 18.378	25.619	30.000	5.714
5	4.2150 4.106 5.660	7.307	6.229	4.843 8.800	22.000	3.333	3.375
6	6.923 9.625 11.250 4.895	12.549	2.244	42.500	0.000	1.800	.400
7	1.082 2.502 10.224 6.570	10.067	17.180	10.937	0.000	18.421	10.000
8	0.000	0.000	1.636	2.266 2.000	0.000	0.000	0.000

Appendix III-09 (cont.)

Station	October	November	December	January	February	March	April
9	0.000	0.000	2.500	1.367	0.000	0.000	0.000
10	0.000	0.000	1.833	2.833	0.000	0.000	0.000

CHAPTER IV

GEOLOGIC ELEMENTS

by

Hershel L. Jones

with the assistance of:

Volker Gobel
Hiram Kelly

TABLE OF CONTENTS

INTRODUCTION

The geological in-depth studies focused on several problem areas which became apparent after the previous research was completed. They included an investigation of the Butler Dome quarry operation with the associated acidic pit and surface water pollution, and a determination of the possible acid and heavy metal contamination resulting from the mining and utilization of lignite by the Big Brown Electric Generation Plant in the vicinity of Fairfield.

The studies also focused on the possible effects of salt water contamination from natural salt masses of the Butler and Palestine salt domes and on the academic value of the stratigraphic type section of the Eagle Ford Formation west of Dallas, and the Cornuspira Carinata fossil locality northeast of the town of Kerens.

An initial effort was made to determine the location of isolated abandoned or depleted oil wells, oilfields, and active or inactive brine disposal pits within the proposed Tennessee Colony reservoir area and along the Trinity River floodplain and its tributaries which may contribute pollution to the river and the Livingston and Wallisville reservoirs. However, it was soon realized that this task would require extensive time searching the files of the Railroad Commission in Austin and in cross checking this information in the field. The time spent would have far exceeded that available for the duration of this contract. Nonetheless, information, e.g., the name, location, producing company, whether or not in production, and pollution problems, of many of the fields is given in Figures 7 (pg. 96), 8 (pg. 100), 9 (pg. 104), and corresponding Tables 3 (pg. 97), 4 (pg. 101), 5 (pg. 105) of a previous report (Stephen F. Austin State University, 1972).

PROCEDURES

Butler Quarry

The following approach was used in the Butler Dome study. The section overlying the quarried stone was first measured and described to determine what proportion of the overburden contains sulfide minerals. Pyrite (FeS_2) veins and nodules and elemental sulfur were detected in 50 feet of the overburden. A representative sample of the sulfide-bearing material was obtained by trenching the entire 50

foot interval. The sample was processed and analyzed to determine the percent of sulfide, sulfur, and heavy metals present.

The redistribution of the overburden and the effect of surface oxidation and leaching on the sulfides in it were carefully observed. A surface drainage map was constructed to portray the general drainage characteristics of the area in order to determine the dispersal of the acid, sulfate and heavy metals being leached from the overburden by surface oxidation (Figure IV-01). The location of the quarry and the redistributed overburden are also shown on this map.

Water samples were taken and analyzed from collection pools in the bottom of the quarry, holding pools downdip from the quarry, collection pools on the exposed overburden, Blue Lake, and where Blue Lake flows into the Trinity River (Figure IV-01).

Fairfield Lignite

In order to study the possible acid and heavy metal pollution problems associated with the activities of the Big Brown Electric Generating Plant, it was necessary to observe their operations and to collect samples. The appropriate personnel of the company were contacted and several guided tours were arranged. They were very helpful in explaining their operation, the extent of their reserves, and in collecting representative samples of the lignite and fly ash. The samples were placed in plastic containers and returned to the laboratory for sample preparation and analysis. The samples were analyzed using atomic absorption, neutron activation, and wet chemical techniques. The location of the Fairfield lignite mining operation, power plant, and the local surface drainage system is given in Figure IV-02.

Palestine Salt Dome

Determination of the possible effects of pollution from natural salt sources in the Palestine Salt Dome drainage area required a field reconnaissance of the area to determine the source of the salt which is contaminating surface waters. Determination of the surface drainage system had to be determined in order to trace the dispersal of the salt water. A surface drainage network map of the area was constructed to accomplish this (Figure IV-03). Water samples were collected from streams draining the Dome

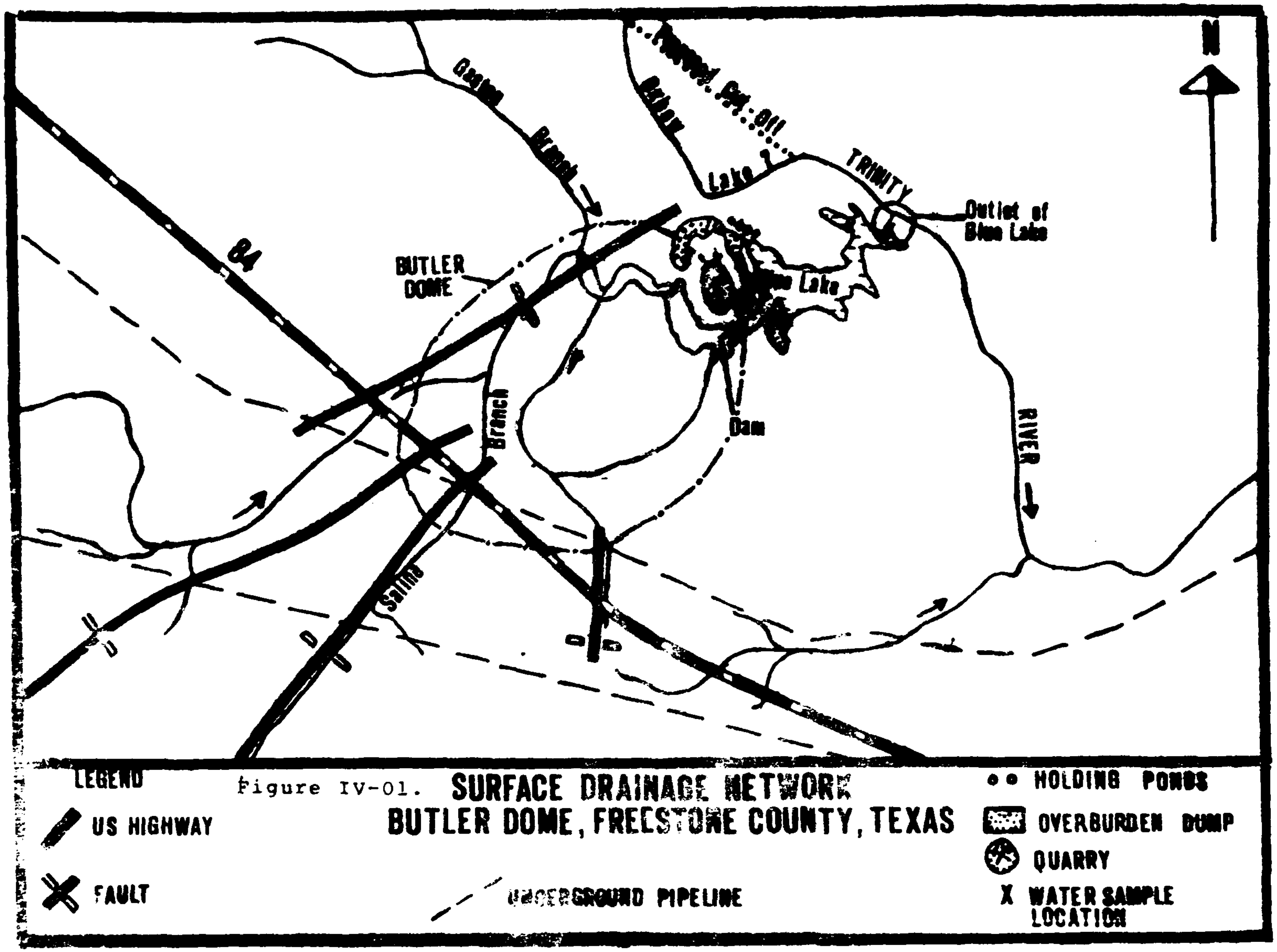
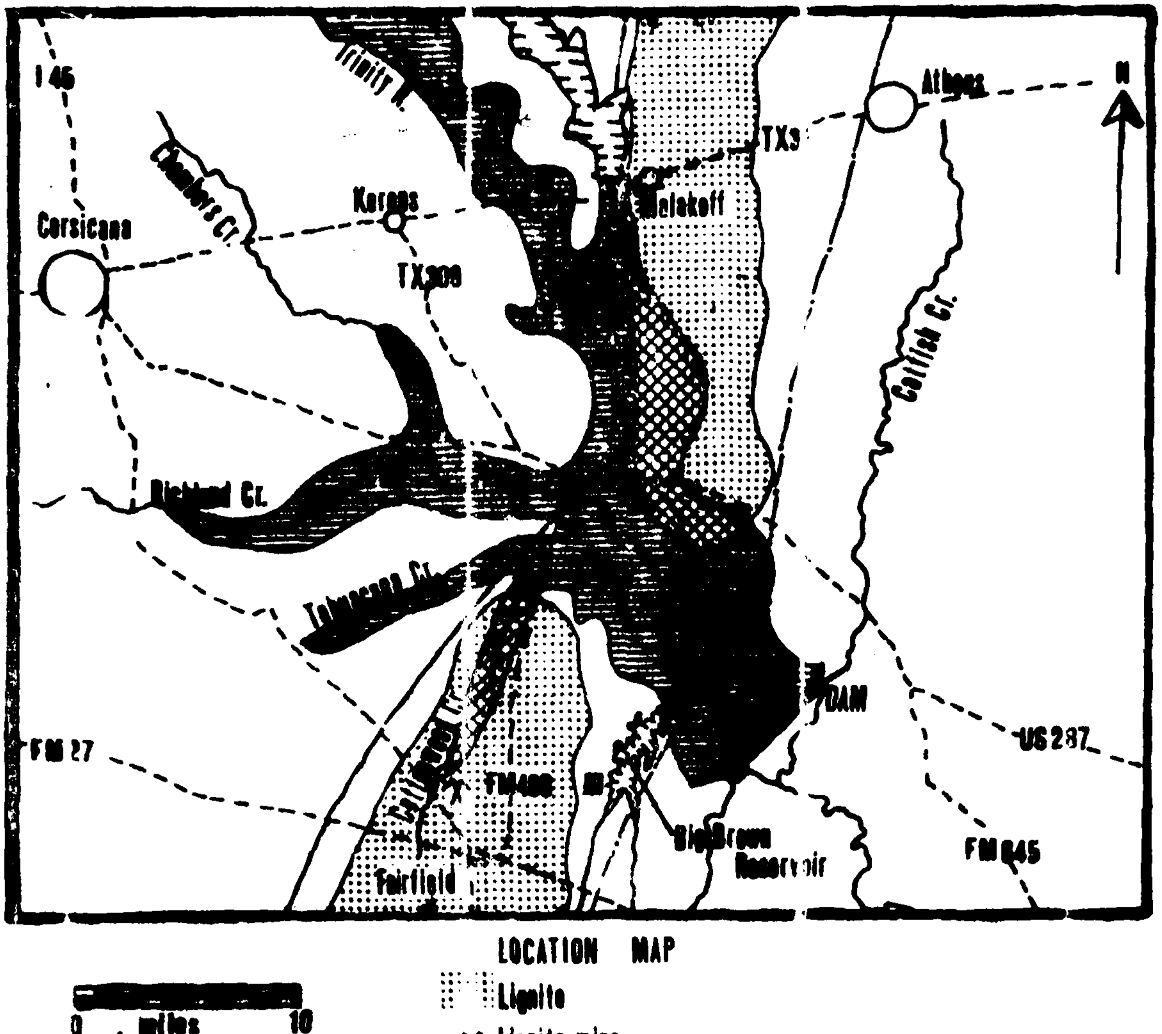


Figure IV-01. SURFACE DRAINAGE NETWORK
BUTLER DOME, FREESTONE COUNTY, TEXAS

Figure IV-02



LOCATION MAP

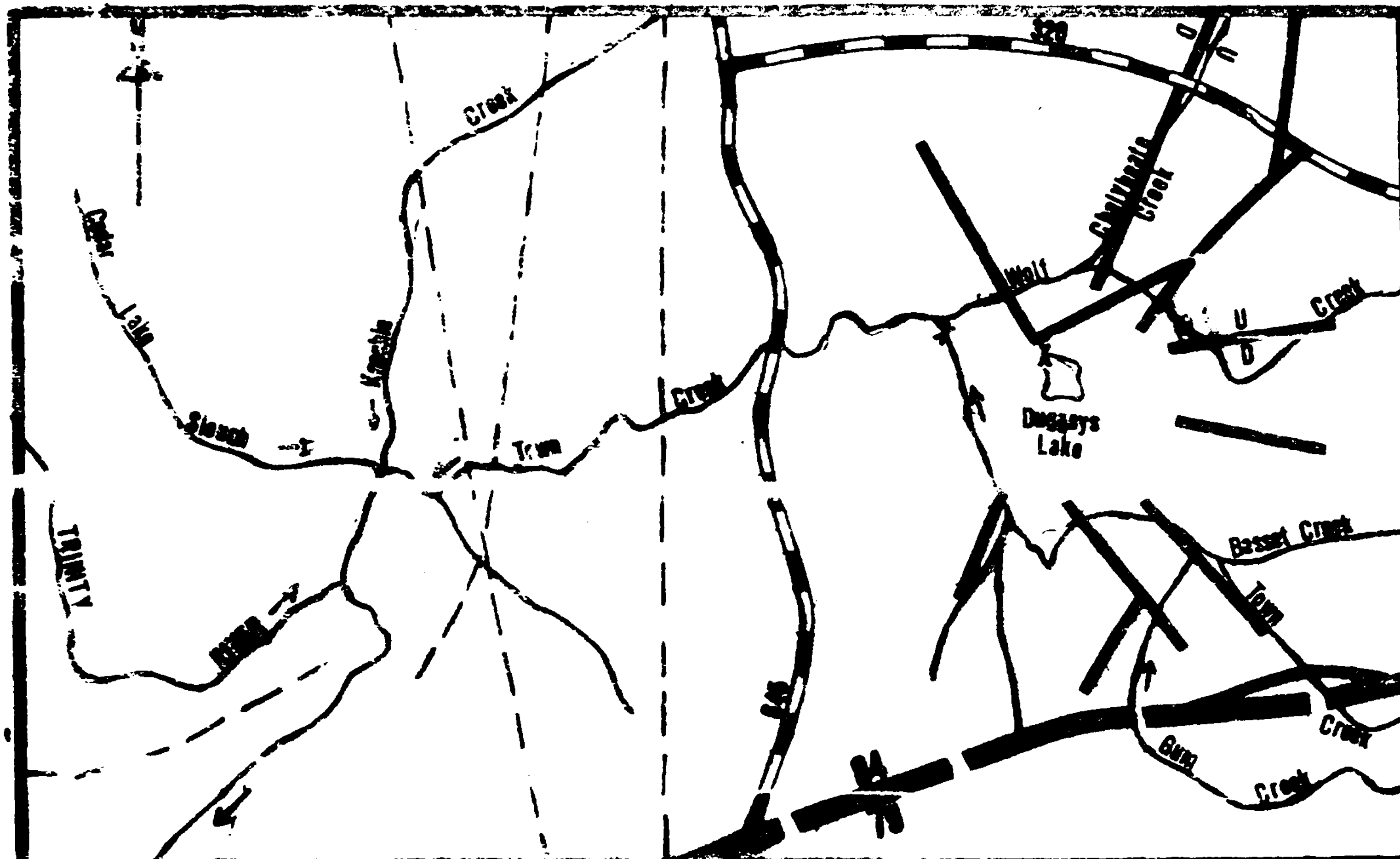
Lignite

Lignite mine

Big Brown Steam Electric Generating Plant

Tennessee Colony Reservoir

Lignite within reservoir area



LEGEND

FAULT

US HIGHWAY

UNDERGROUND PIPELINE

FARM TO MARKET ROAD

X WATER SAMPLE LOCATION

Figure IV-03. SURFACE DRAINAGE NETWORK
PALESTINE DOME, ANDERSON COUNTY, TEXAS

area to determine if salt pollution is occurring and if so, to what extent. The samples were taken to the laboratory and analyzed for chlorides and sulfates.

Eagle Ford and Kerens Member Type Sections and Cornuspira carinata Fossil Locality

Location of type geological sections are frequently difficult because many were described years ago and referenced to the existing landmarks which may or may not now exist. A search of the literature was necessary to locate the original description and location of these type sections. Even then it required considerable field work to locate them. After location, the type sections were measured and described and compared to the original description. The locations of the type geological sections and the fossil locality are shown in Figures IV-04, 05, and 06.

RESULTS

Butler Dome Quarry

Widespread progressive chemical decomposition of the iron sulfide mineral pyrite caused by weathering processes was observed in the overburden dumps and in the 50-feet of exposed material overlying the quarried stone. Some of the iron released during this process is being redeposited as iron oxide coatings on the quarry cliff faces and in the water collection pools. Part of the sulfur released occurs as elemental sulfur on the quarry walls and on the overburden dumps, but much of it reacts chemically with surface water producing sulfur-containing acids. Surface runoff from the dumps and from the exposed overburden above the quarry stone drains into the quarry, holding ponds, collection pools on exposed overburden, and in Blue Lake concentrating acids, sulfate, and heavy metals.

Their dispersal is shown on a general location map (Figure IV-01) of the area depicting the quarry, the location of the redistributed overburden material, and the local drainage system.

Approximately 2.8 million tons of overburden has been removed and redistributed by the Butler Dome quarry operation. It is anticipated that at least an additional million tons will be removed in the future. Table IV-01 gives data for the different forms of sulfur and the heavy metals in the overburden material. Approximately 45,600

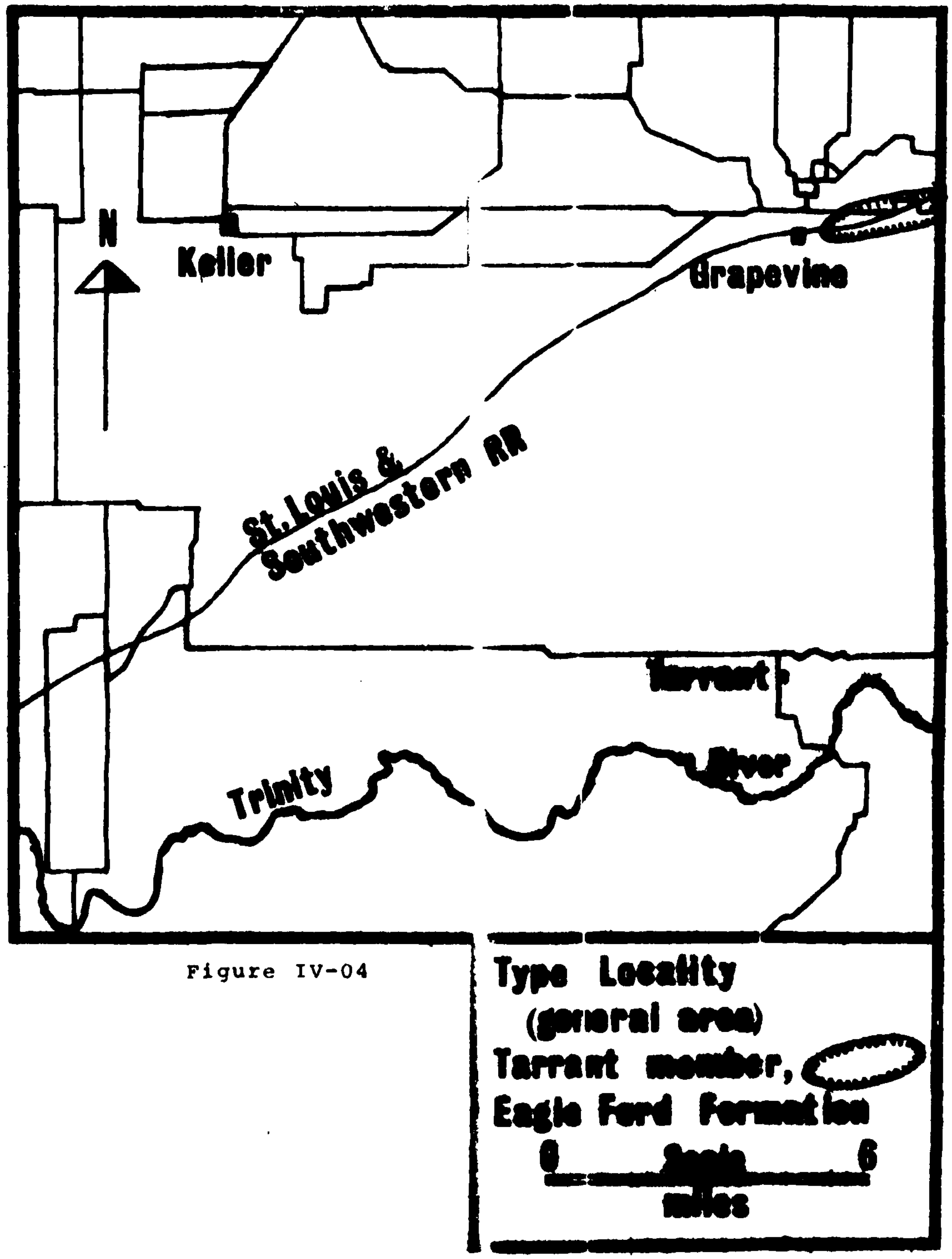

N
Keller
Grapevine
St. Louis &
Southwestern RR
Tarrant
Trinity
River
Type Locality
(general area)
Tarrant member,
Eagle Ford Formation
0 Scale 6
miles

Figure IV-04

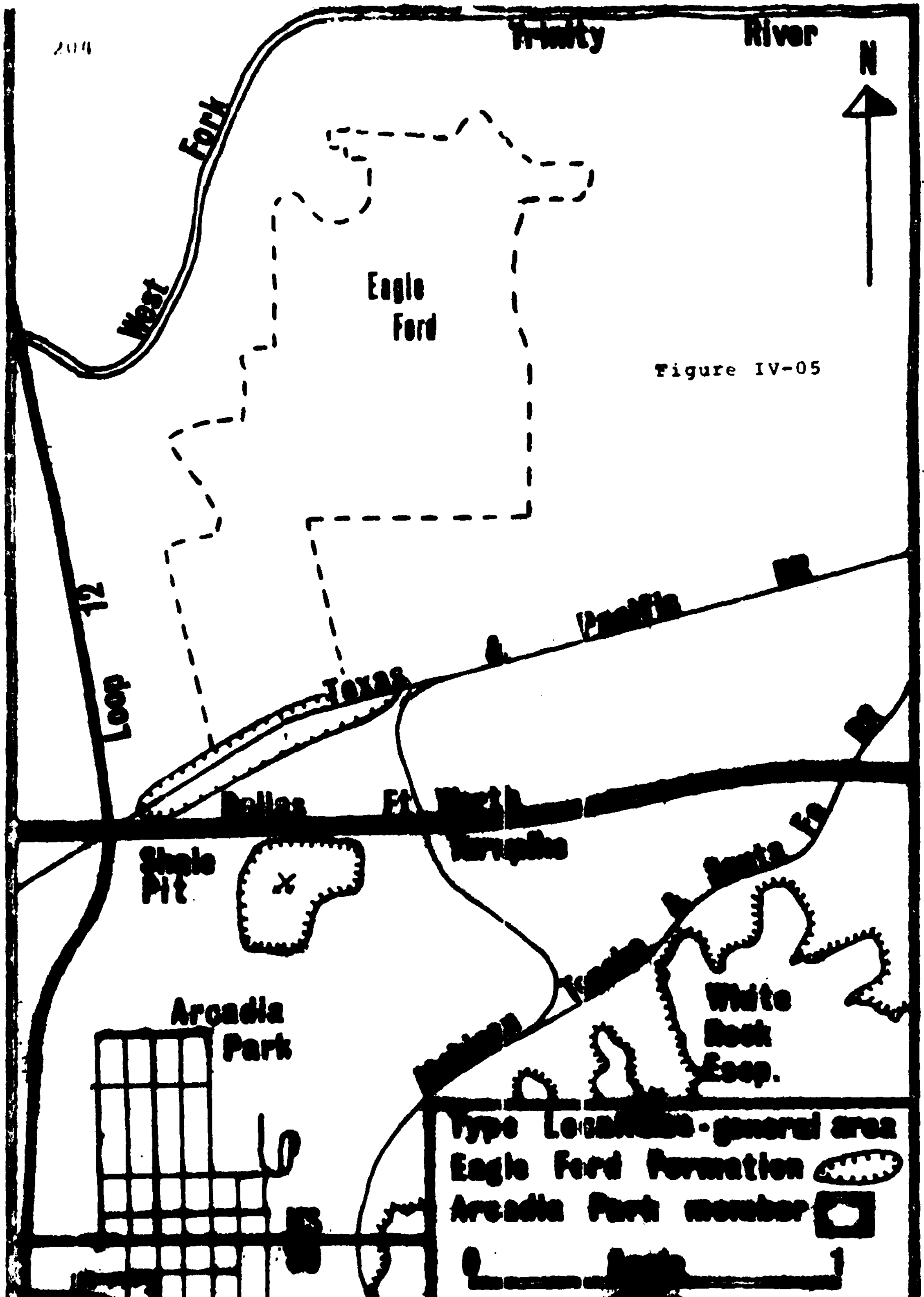
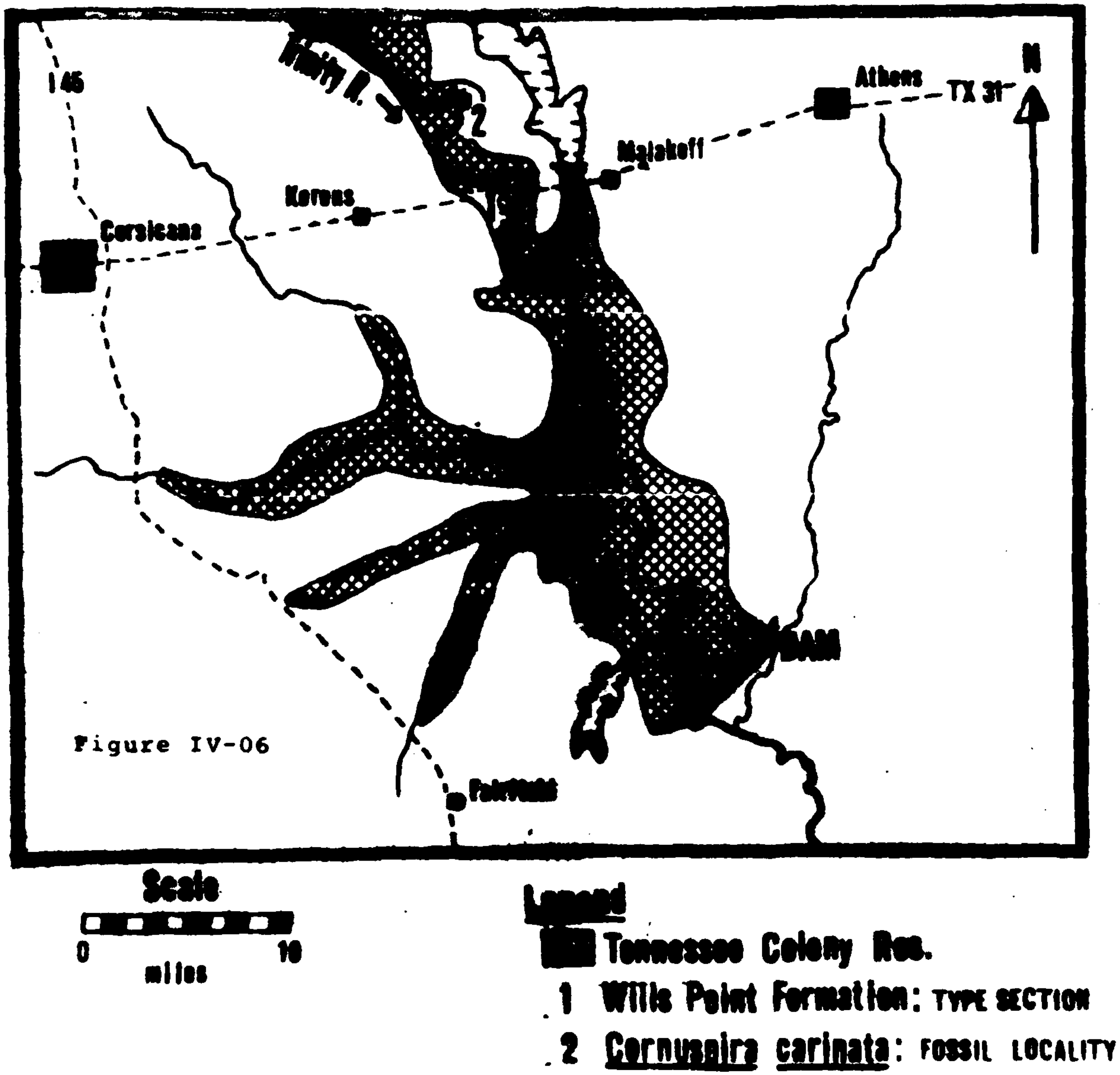

West Fork Trinity River
N
Eagle Ford
Loop 12
Texas
Pacific
Dallas Ft Worth
Turnpike
Shale Pit
Santa Fe
Arcadia Park
White Rock Escp.
Eagle Ford Formation
Arcadia Park member
0
1

Figure IV-05



Trinity R.
2
Athens
TX 31
N
I 45
Malakoff
Kerens
Corsicana
DAM
Fairfield
Scale
0
10
miles
Legend
Tennessee Colony Res.
1 Wills Point Formation: TYPE SECTION
2 Cornuspira carinata: FOSSIL LOCALITY

Figure IV-06

tons of total sulfur are present. About 10,000 tons, or approximately 28 percent of the total amount, are readily soluble. The remaining sulfur is still tied up in the oxidizing pyrite.

Water samples taken from collection pools in the bottom of the quarry, collection pools on the overburden, from Blue Lake, and its outlet into the Trinity River (Figure IV-01) permitted the determination of the present effects of the quarry operation on the chemical composition of the water. Table IV-02 summarizes the analytical results.

The composition of the water varies with the amount of precipitation because of the subsequent dilution. The data given are for a wet season during which the backwater of the flooding Trinity River occasionally inundated the lowland area adjacent to the quarry and Blue Lake. At high floodstage the water backs up against the displaced overburden of the quarry and a water exchange between river and Blue Lake takes place.

Water from the holding ponds and collection pools on the overburden is very acidic and has a high sulfate content. The sulfate content of the water in the collection pools in the bottom of the quarry is also high; surprisingly, the water is less acidic than expected. Dilution of the quarry water as a result of unusually heavy rainfall and the reaction of the acidic water with calcium carbonate ($CaCO_3$) in the quarried rocks could account for this unexpected situation. High carbonate concentrations occur in the bottom pit water of the quarry.

The sulfate content of Blue Lake water and its outlet to the Trinity River is lower than that of water close to the quarry but is still significantly high as compared with average lake water. The pH is higher than expected but could be explained in part by the dilution of the lake water by the inflow of large quantities of water during the rainy season.

Heavy metal concentrations in the overburden from the quarry (Table IV-01) are as follows:

(1) mercury 0.75ppm
(2) cadmium 3.7ppm
(3) lead 417ppm
(4) arsenic 5.4ppm
(5) selenium 3.1ppm.

Table IV-01. Sulfur and heavy metal contents (in weight percent and parts per million) of overburden material from the Butler Dome quarry.*

	Concentrations	Total Tons Present
Water soluble sulfate sulfur	0.15 wt.%	5,700.0
Water insoluble sulfate sulfur	0.00 wt.%	00.0
Elemental sulfur	0.12 wt.%	4,560.0
Sulfide sulfur	0.98 wt.%	37,240.0
Total sulfur assay	1.20 wt.%	45,600.0
Mercury	0.75 ppm	2.9
Cadmium	3.7 ppm	14.1
Lead	417.0 ppm	1,585.0
Selenium	3.1 ppm	11.8
Arsenic	5.4 ppm	20.5
Total moisture content	6.10 wt.%	231,800.0

*The data are the result of assays for the different forms of sulfur performed using a representative sample. The amount of 3.8 million tons of overburden was used in computing the tonnages.

Table IV-02. Results of chemical analyses (in parts per million) of water samples from Butler Dome quarry and vicinity

Sample	Location	Month Collected	pH	SO_4	Pb	Co	Hg	As
1	Collection Pool inside quarry	Nov.	7.7	750.0	*	*	0.022	9.0
		May	6.7	840.0	*	*	0.018	7.0
2	Collection pools on overburden	Nov.	2.6	7300.0	*	*	0.040	0.0
3	Holding ponds downdip from quarry	Nov.	2.8	1700.0	*	*	0.018	0.0
		May	2.9	570.0	*	*	0.022	0.0
4	Blue Lake adjacent to quarry	Nov.	7.1	140.0	*	*	0.020	0.0
5	Central part of Blue Lake	Nov.	8.0	152.0	*	*	0.017	0.0
6	Outlet of Blue Lake to Trinity River	Nov.	7.9	70.0	*	*	0.020	0.0
		May	6.6	76.0	*	*	0.016	0.0

* Less than lower limit of detection as follows: lead 2 ppm, cadmium 0.2 ppm, and arsenic 1.0 ppm.

The results of chemical analyses of water samples from the quarry and vicinity are given in Table IV-02. The mercury content of water samples from collection pools on the overburden (40ppm), from inside the quarry (20ppm), and from Blue Lake (approximately 20ppm) (Figure IV-01) exceed the maximum considered safe for drinking water (5ppb--U.S. Public Health Service, 1962). Cadmium and lead concentrations in water samples from the quarry vicinity and from Blue Lake were below the limit of detection (0.2ppm and 2.0ppm, respectively) of the atomic absorption unit used. Water samples from the collection pool inside the quarry averaged 8ppm which is considerably greater than the 50ppb considered safe by the U.S. Public Health Service. Arsenic was not detected in water samples from Blue Lake, however.

Fairfield Lignite

Mercury analyses of samples of the Fairfield lignite and power plant ash were performed by neutron activation analyses and double gold amalgamation-flameless atomic absorption spectrophotometry. Results obtained by neutron activation analyses were not as reliable as those obtained by double gold amalgamation-flameless atomic absorption spectrophotometry and were thus not included in this report. The results of the analyses by the latter are given in Table IV-03. Trace element results of a composite sample are given in Table IV-04. Figure IV-02 shows the location of the power plant and lignite pits. The mercury content varies for samples taken from pits A and B and the stock piles. The calculated averaged value is 0.30 ppm Hg. That corresponds quite well to the 0.35 ppm figure obtained for a composite sample representing materials from pits A and B, the unloading dump and the stock piles. Therefore, this figure of 0.35 ppm Hg can be taken as representative for the mercury content of the Fairfield lignite.

Combined bottom and precipitated fly ashes constitute approximately 14 weight percent of the total lignite burned, and contain approximately 0.05 ppm Hg.

Based on annual lignite consumption of 3,600,000 tons (dry coal basis), approximately 1.26 tons per year of mercury is mobilized. Of this amount released by burning, only 2 percent or 50 pounds is retained in the fly ash.

The fate of mercury upon burning of the coal is diverse. It escapes out of the stack together with the gases and may partly be absorbed on the fly ash and the interior walls of the furnace and stack system.

Table IV-03. Mercury contents for Fairfield Lignite and ash from the Big Brown Power Plant *

Sample	Location	Hg (ppm)
1	Pit A	0.18
2	Pit B	0.34
3	Power Plant Stock Pile	0.39
4	Power Plant ash	0.06

* Analyses were performed by double gold amalgamation-flameless atomic absorption spectrophotometry.

Table IV-04. Trace element contents of composite samples of Fairfield lignite and power plant ash*

Element	Concentrations in Lignite	Concentrations in Ash	Amounts of Elements in Lignite	Amounts of Elements in Ash	Loss Lignite	Retained Ash
Hg	0.35ppm	0.05ppm	1.26s.t.	0.025s.t.	98%	2%
Pb	17.00ppm	41.40ppm	61.20s.t.	20.87s.t.	66%	34%
Cd	1.16ppm	7.40ppm	4.18s.t.	3.73s.t.	11%	89%
Se	8.50ppm	5.40ppm	30.60s.t.	2.72s.t.	91%	9%
As	0.9ppm	1.20ppm	3.24s.t.	0.61s.t.	19%	81%
Sc	3.2ppm	23.00ppm	11.52s.t.	15.59s.t.	0%	100%
Total S (weight percent)	0.87%	0.16%	31,320.00s.t.	806.00s.t.	97.4%	2.6%

Total moisture (+105°C) 35.39%

* All results are on a dry coal basis, and the tonnage of each element computed is on the basis of an annual lignite consumption of 3.6 million short tons with a 14 percent ash content.

The fly ash is removed from the furnace emissions by electrostatic precipitators and is combined with the bottom-ash. The combined ash is sent through a slurry line to a collection pit from which it is removed and used as road base material.

The mercury content of the slurry pit ash is about 0.05 ppm Hg. Some of this mercury in road base material may ultimately escape to the atmosphere and the ground water because mercury begins to volatilize at a temperature of about 80°F. Dissemination of the ash as road material could possibly result in wide dispersal of the mercury due to this volatilization under hot weather conditions during and after road construction.

It can be assumed that the majority of the mercury escapes directly to the atmosphere because airborne surveys (Hearings, p. 162, 1971) detected large concentrations of up to 10,000 ng/m^3 of mercury in the plumes discharged from the smokestacks of coal-burning power plants.

Other elements in the Fairfield lignite (Table IV-04) analysed include lead, cadmium, selenium, arsenic, scandium, and sulfur. Various amounts of these elements are not retained in the ash, and have most likely been emitted with the stack emissions. Sulfur occurs mostly as sulfur dioxide gas. Lead, cadmium, selenium, and arsenic probably exist as volatized heavy metal atoms.

Butler and Palestine Salt Domes

Results of water sample analyses from the drainage areas of Butler and Palestine salt domes are given in Tables IV-05 and IV-06. Surface drainage is pictured in Figures IV-01 and 03.

In December 1972, sodium and chloride concentrations in the water entering the Trinity River through the outlet of Blue Lake were higher than for regular lake water. Blue Lake is the collection basin for all the drainage from the Butler Salt dome. Lower concentration values were obtained for samples collected during May, 1973. This can be explained by the recent dilution of lake water by heavy rains, and by an exchange of Trinity River flood waters with the water of Blue Lake. The results indicate that most of the chlorides come from the salt dome surface drainage rather than from the quarry operation on the north flank of the dome.

Table IV-05. Results of chemical analyses of water samples (in parts per million) for chlorides from Butler Dome and vicinity.

Sample	Location	Month Collected	Na	Cl
1	Collection pool inside quarry	Dec. May	44 50	35 40
2	Collection pools on overburden	Dec.	6.6	*
3	Holding ponds downdip from quarry	Dec. May	0.2 4.2	* 85
4	Blue Lake adjacent to quarry	Dec.	62	80
5	Central part of Blue Lake	Dec.	64	180
6	Outlet of Blue Lake to Trinity River	Dec. May	70 28	180 40

*Below detectable limit.

Table IV-06. Results of chemical analyses of water samples from the Palestine Dome vicinity.

Sample	Location	Month Collected	Na (ppm)	Cl (ppm)	pH	SO_4
1	Duggey's Lake	Nov.	1600	5600	7.0	144
2	Wolt Creek	Nov.	40	60	7.4	52
3	Town Creek at bridge on Highway 645	Nov.	42	60	7.0	52
		May	50	70	6.4	82

Extremely high concentrations of chlorides were observed in the water from Duggey's Lake which is located near the center on the Palestine dome. Salt flats occur on the flanks of the dome. However, these high concentrations of chlorides have not been observed in the drainage waters farther away from the dome. Wolf Creek and Town Creek waters have fairly low chloride concentrations. Town Creek discharges into the Trinity River above the proposed Tennessee Colony reservoir.

Type Localities

The type localities of the Eagle Ford Formation, Gulf Series, Cretaceous as named and and described by Hill (1887) are situated around the small settlement of Eagle Ford approximately 1 mile south of and some 60 feet above the present Trinity River floodplain (Figure IV-04). These localities are numerous and are so far away from the river that they would not be disturbed by channelization activities. Detailed information concerning the stratigraphy of the Eagle Ford Formation is given in Table IV-07.

The Eagle Ford Formation has been divided into three members: Tarrant, Britton, and Arcadia Park, in ascending order from older to younger by Moreman (1927). The type locality of the Tarrant member is located east of Grapevine at the crossing of the St. Louis, San Francisco, and Texas railways over a tributary of Bear Creek approximately 9 miles north and well above the Trinity River (Figure IV-05). The stratigraphy of these units is described in detail in Table IV-07.

The type locality of the Kerens member of the Wills Point Formation and the Cornuspira Carinata fossil locality of the Kerens member located northeast of Kerens (Figure IV-06) will both be inundated by the Tennessee Colony Reservoir. No suitable alternative localities have been found up to now.

DISCUSSION AND CONCLUSIONS

Butler Dome Quarry

The results of this study confirm the previous belief that a serious acid water pollution problem does exist in the vicinity of the Butler quarrying operation. Surface drainage from the overburden dumps quarry and holding ponds transports acid, sulfate, and heavy metals into Blue

Table IV-07. Stratigraphy of the Eagle Ford Formation, Gulfian, Cretaceous; Eagle Ford Vicinity.

System	Series	Group	Stratigraphic Unit	Approx. Thickness (feet)	Physical Characteristics of Rock Unit
Upper Cretaceous	Gulfian	Eagle Ford	Arcadia Park Shale	100±	Clay, shale and limestone. Basal portion clay (20 feet), separated from upper shaley portion (75 feet) by thin limestone flags (1-3 feet). Numerous calcareous concretions in upper portion.
			Britton	300±	Clay, marl, and shale with some limestone seams, calcareous concretions, and bentonite seams.
			Tarrant	15±	Clay, sandy, limestone and calcareous concretions.

Lake, which in turn, discharges into the Trinity River. At the present time, this does not appear to affect seriously the chemistry of the water in Blue Lake because of the continuous flow of water from Blue Lake into the Trinity River, and also the frequent influx of water from the Trinity River into Blue Lake during flood periods.

This situation will change if the proposed cut-off of the Trinity River during channelization is done. This creates a man-made oxbow lake north of the quarry (Figure IV-01). Realignment of the channel would prevent flooding and frequent exchange of water between river and lake. The large quantities of available acid, sulfate, and heavy metals in the waters could ultimately affect adversely the water quality of Blue Lake which in turn would affect the water quality of the Trinity River below the oxbow lake. Fortunately, the outlet of Blue Lake is below the proposed cut-off and the discharge from the lake will not flow into the oxbow lake. There is, however, the possibility of minor pollution of the lake by surface water drainage from the overburden dump and holding ponds during heavy rains.

Fairfield Lignite

Results for the Fairfield lignite and fly ash from the power plant show that a potentially serious mercury, sulfur dioxide, and heavy metal pollution problem exists due to the activities of the Big Brown Electric Generating Plant.

The magnitude of the emissions problem can only be assessed after an aerial wind dispersal study has been made. The problems of atmospheric transport and environmental accumulation should be investigated over a long period of time to determine the severity of this problem. Prevailing winds from the southwest to the northeast could feasibly cause the accumulation of mercury in Big Brown reservoir, Cottonwood Creek, Trinity River, and the proposed Tennessee Colony Reservior.

Mercury pollution poses a serious environmental problem because of the tendency of mercury to be concentrated in the food chain.

Lead, cadmium, and selenium pose similar problems. These elements are serious pollutants and also constitute an acute health problem caused by heavy metal poisoning, as has been demonstrated in previous studies (Texas State Health Department, 1972).

Butler and Palestine Salt Domes

Some natural salt pollution of the surface drainage exists in the Butler and Palestine salt dome areas. Analyses of water samples for chlorides indicate that the problem is more severe in the Butler Dome area. Surface runoff from Butler Dome concentrates chlorides in Blue Lake, which drains into the Trinity River. The problem will become more serious if channelization produces an artificial oxbow lake just to the north of Blue Lake. It would reduce dilution of the lake water by overflow from the river and allow chlorides to concentrate in higher amounts in Blue Lake. Polluted water from Blue Lake would flow into the Trinity River below the oxbow lake and affect the water quality of the river.

Severe salt pollution of surface water occurs in the Palestine dome proper but considerable dilution appears to occur before this water enters the Trinity River via Town Creek.

Type Localities

The type localities of the Eagle Ford Formation west of Dallas are too far away from the river to be affected by channelization.

The type locality of the Kerens member of the Wells Point Formation and the Cornuspira Carinata fossil locality of the Kerens member located northeast of Kerens will both be inundated by the Tennessee Colony Reservoir, and suitable alternative localities have not yet been located.

It is felt that the flooding of the type locality of the Kerens member and and the Cornuspira Carinata fossil locality will not be an important loss. Both localities have been adequately described, and new satisfactory alternatives could probably be located.

ADDENDUM

This addendum entitled Preliminary Report on the Status of the Oil and Gas Wells in the Proposed Tennessee Colony Reservoir Area, Trinity River, Texas was prepared by Martha Robins Stokes under the supervision of Dr. Hershel L. Jones

***

A supplemental study was made of the oil and gas wells of the Tennessee Colony Reservoir area using 1953 (updated to 1963) Heydrick ownership and oil development maps by Acme Map Co., Tyler, Texas. Six maps were used covering portions of Anderson, Freestone, Henderson, and Navarro counties. Based on the maps, a count revealed 414 wells in the floodplain (flood pool elevation 297 feet) of the proposed Tennessee Colony Reservoir area. Two hundred and forty of these wells were shown to be producing, with the remainder being dry or abandoned. The breakdown is as follows:

Producing oil wells	164
Producing gas wells	64
Producing gas and oil distillate	12
Total	240
Dry or abandoned holes	130
Abandoned oil	38
Abandoned gas and oil distillate	1
Abandoned gas	5
Total	174

Due to the limited time available for this study, six percent of the total wells were randomly sampled and further investigated in an attempt to determine what percentage of the shown producing wells were still producing and to determine what percentage of those shown to be abandoned or depleted were plugged and the plugging techniques. On the basis of this information, an attempt was made to statistically determine the number of wells still in production; the number of wells abandoned or depleted; and the number plugged and the plugging techniques.

The investigation was accomplished by using the available records for District Five and Six at the Railroad Commissioner's Office in Kilgore, Texas. This amounted to checking the records and data on 13 producing (including 2

shut-in) and 12 dry or abandoned wells (some plugged and some not plugged).

During the course of this study, problems arose that required changes in well sampling techniques, possibly affecting the accuracy of the data obtained. The antiquated maps and in some cases the incomplete records, (drilling, deepening, and plug-back) on file at the Railroad Commissioner's Office due to the negligence of oil and gas operators, are examples of problems encountered. The merging and liquidating of leases and operators and the renumbering of wells by the new operators when leases are changed altered sampling techniques.

The assistance of the employees in the records room was essential because in many cases wells that were shown on the maps did not exist any longer, or existed as a newly numbered well or on a new lease with a new operator.

Producing wells had to be checked by using both the files (drilling or deepening records only) and the Gas and Oil Schedules for District Five and Six and the Gas and Oil Production Schedules for District Five and Six. These schedules consist of current computer-printed information by county, field, operator, lease, and well number. They give monthly allowables and monthly production per thousand cubic feet or barrels for the lease and individual wells.

Of the 13 wells shown as producing, records indicate that 5, or approximately 38 percent, have been depleted, shut-in, or abandoned (see Table IV-08). Assuming this figure to be representative, approximately 147 wells should still be in production. Wells drilled since 1963 do not appear on the maps and are therefore not included in this survey. It should be noted, however, that exploration and development has continually occurred since that time, and the above data does not reflect the current situation.

Two of the 12 dry and abandoned wells sampled (or approximately 20 percent) were not plugged and the files contained no record of plugging. Utilizing the figure of 20 percent, approximately 34 of the 147 dry and abandoned wells would not be plugged (see Table IV-09).

In addition, 1 of the 5 wells, or approximately 20 percent of the dry and abandoned wells that were shown to be producing on the maps, contained no record of plugging.

Thus, approximately 18 of 93 dry and abandoned wells were not plugged, giving a grand total of 52 wells not plugged in the Tennessee Colony Reservoir area.

Information from the files shows that the plugged wells surveyed conformed essentially to the general conservation rules and regulations of statewide application as set forth by the Railroad Commission of Texas, 1964 Recodification, supplimented to June 1, 1973 (see Table IV-11).

Data pertaining to production and plugging techniques are found in Tables IV-10 and IV-11, respectively.

Mr. James Smith, Director of the District Five and Six Railroad Commission, is well qualified to render a decision based on his experience and knowledge of the area, pertaining to the overall plugging conditions and the potential likelihood of pollution resulting from future blowouts. He has indicated a willingness to cooperate in this matter, and it is recommended that he be asked to submit a written statement to this effect.

Table IV-08. Randomly selected producing wells, including 2 shut-in wells, Tennessee Colony Reservoir area, Trinity River Texas.

Well No.	Location	Field	Producing or Dry	Operator	Lease	Survey
27	Freestone Co. 660' S 1650' W of H. Berk-location	Cayuga-Trinity	Prod.	Amerada	H. Berk	Rector A 531
1	Navarro Co. 330' NW of SW line; 1370' SW of NE line of 137 acre tract of lease	So. Kerens (Woodbine Formation)	Prod.	Humble Oil	P. T. Pullwood, et al.	W.M. Love A-677
21 (formerly 2 under Clyde H. Alexander)	Navarro Co. Creslenn Ranch "B" 660' E line, 6300' from S line of McKinney & Williams survey	Cayuga	Shut-in	W.C. Perryman	Cayuga NW Unit Rodessa	McKinney & Williams A-609
20 (formerly 1)	Navarro Co. Creslenn Ranch "C"	Cayuga	Shut-in	W.C. Perryman	Cayuga NW Unit Rodessa	McKinney & Williams A-609
6 (formerly A-1 Creslenn Ranch	Henderson Co.	Cayuga	Prod.	W.C. Perryman	Cayuga NW Unit Rodessa	R.W. Chappel A-140

Table IV-08 (cont.)

Well No.	Location	Field	Producing or Dry	Operator	Lease	Survey
11 (formerly Stevens Lake Land Co.-#1 Murchison Opr.)	Henderson Co.	Cayuga	Prod.	W.C. Perryman	Cayuga NW Unit Rodessa	Wm. Keese A-419
1B	Anderson Co.	Cayuga	Prod.	Double Diamond Pet.,Inc.	7-11 Ranch "B"	Michael Ellis A-278
2	Anderson Co.	Cayuga	Prod.	Ed Overton & W. E. Richey	7-11 Ranch "B"	Ellis A-278
1D	Anderson Co.	Cayuga (Trinity Formation)	Prod	Getty Oil Company		Jas. A. Wilson A-793
1	Navarro Co.-Unit 1	So. Kerens (Woodbine)	Prod.	Exxon	N. Davidson Blaize	Wm. A. Love A-677
2	Navarro Co.	So. Kerens (Woodbine)	Prod.	Exxon	1st Natl. Bank of Corsicana	Robt. Caradine A-139
1	Navarro Co.	So. Kerens (Woodbine)	Prod.	Texaco,Inc.	W.M. Montgomery	E. Powers A-633
1	Freestone Co.	Cayuga-Trinity	Prod.	G.C. Clark	Hettie Berk	E.G. Rector A-531

Table IV-09. Randomly selected dry and abandoned wells, plugged and unplugged, Tennessee Colony Reservoir area, Trinity River, Texas

Well No.	Location	Field	Plugged or Not Plugged	Operator	Lease	Survey
18	Freestone Co.	Cayuga	Plugged (Abandoned)	Amerada	H. Berk	E.G. Rector A-531
24	Freestone Co.	Cayuga	Plugged (Abandoned)	Amerada	H.Berk	Rector A-531
1	Henderson Co.	Wildcat	Plugged(revealed by field insp.) but no plugging data filed.	T.C. Morrow	Mary Harwell	C.E. Miller A-1028
2	Henderson Co.	Wildcat	Plugged (revealed by field insp.)	T.C. Morrow	Mary Harwell	C.E. Miller A-1028
1	Henderson Co. 330' from N line,1500' from W line of Trinity Farms Security Co. lease	Wildcat	Not Plugged (Abandoned)	Texas Co.	Trinity Farms Securities	C.E. Miller A-1028
1	Henderson Co. 3 miles W of the town of Tool	Flag Lake	Plugged (Dry)	Wheelock-Weinschel	J.P. Tarkinton, et al.	Wm.K. Newell A-593
3	Navarro Co. (Flag Lake extn.)	Bazette Field	Plugged (Dry)	W.W. Lechner	W.L. Crowley	R.H. Matthews A-518

Table IV-09 (cont.)

Well No.	Location	Field	Plugged or Not Plugged	Operator	Lease	Survey
1	Navarro Co. 10 mi. NE from town of Kerens	Bazette	Not Plugged (Abandoned)	Trebole (formerly T.C. Morrow)	Sarah B. Tramel	P. Norton A-623
1	Henderson Co. 1600' from E line; 850' from S line	Trinidad	Plugged (Abandoned)	Amoco Prod. Co. (formerly Pan Am)	Hoffman Gas Unit	Jos. Bartlett A-105
1	Henderson Co. 6250' from E line; 3600' from N line; 660' NE of Trinity River	Wildcat (Woodbine Formation)	Plugged(Dry)	Ralph Spence	Xenia Miller	Geo. J. Johnston A-395
1	Henderson Co.	Cayuga (Woodbine)	Plugged(Dry)	Slago Oil Co.	W.R. Kinabrew	Jose Ysidro Perez A-605
2	Henderson Co.	Cayuga NW	Plugged(Dry)	J.W. Murchison Co.	Creslenn Ranch	J.P. McCullars A-1045

Table IV-10. Production data of randomly selected producing wells, including two shut-in wells, Tennessee Colony, Trinity River, Texas

Well No.*	Type Well	Platform Elevation	Total Depth	Top Pay	Perforations	Producing	Surface Casing Oil String, Tubing
27	Prod.- oil	255'	7630'	7517'	7554'to7560'	17bbls/d.	8-5/8"- 753' 4-1/2"-7629' 2-3/8"-7430'
1	Prod.- oil	283'	3450'	----	-----------	50bbls/d. Gas Limit 128 MCF	10-3/4"-206.29' 7" - 3440.42' 2-1/2"-3391.48'
21	Shut-in oil	273.3'	7334'	7293'	7293-95' to 7299.5-7301.5'	--------	8-5/8"- 770' 4-12/"-7334' 2-3/8"-7253'
20 (formerly 1)	Shut-in oil	272'	7394'	7377'	7377'-78'to 7381'-83'	--------	8-5/8"- 761' 4-1/2"-7394' 2-3/8"-7320'
6 (formerly A-1)	Prod.- oil	268'	7398'	7350'	7373.5-7374.5 to 7377'-79'	35bbl.oil 14MCF gas	8-5/8"- 788' 5-1/2"-not record. 2-3/8"-7380'
11 (formerly 1-Stevens Lake Land Co.)	Prod.- oil	268'	8646'	7434'	7439'-7447'	2 bbl.oil 18 H_2O 1 MFC gas	8-5/8"- 746' 5-1/2"-8646' 2-3/8"-7429'
1B	Prod.- oil	273'	4075'	4021'	4021'-4023'	5bbl Oct.'73	10-3/4"- 624' 5-1/2"-4075'

Table IV-10 (cont.)

Well No.*	Type Well	Platform Elevation	Total Depth	Top Pay	Perforations	Producing	Surface Casing, Oil String, Tubing
2	Prod.- oil	270'	------	-------	------------	62bbl. Oct.'73	8-5/8"- 112' 4-1/2"-4058' 2-3/8"-3978'
1D	Prod.- gas	---	4047'	prod.from Trinity Form.	-----------	148 MCF Oct.'73	10-3/4"- 602' 6-5/8"-4022'
1	Prod.- oil	287'	3422'	3370'	3370'-3378'	8,772bbl. Oct.'73	10-3/4"- 206.71' 7" - 3415' 2-1/2"-3381.50'
2	Prod.- oil	282'	3450'	3372'	3372'-3378'	1,271 flowing bbl.	8-5/8"- 594.89' 5-1/2"-3439.0' 2-1/2"-3373'
1	Prod.- oil	276'	3464'	------	3412'-3415'	0-Oct.'73	10-3/4"- 539' 5-1/2"-3464' 2" - 2332'
1	Prod.- gas	257'	7500'	------	7420'-7460'	2,653MCF Oct.'73	8-5/8"- 633' 4-1/2"-7500' 2" -7283'

* Corresponds to order used in Table IV-08.

IV-11. Plugging data of randomly selected dry and abandoned wells, plugged and unplugged, Tennessee Colony Reservoir area, Trinity River, Texas

Well No.*	Type Well	Platform Elevation	Date Plugged	Total Depth	Formation Thickness	Plugging Data
18	Abandoned & plugged oil well	253'	8/10/62	4028'	3990-95' oil	25 sx. cement plug 3998'-3793' mud from 3793'-694' 10 sx. cement plug 694'-664' mud from 664'-30' 10 sx. from 30' to 0'
24	Abandoned & plugged oil well	246'	9/29/60	4019'	3994'-4004'	25 sx. cement plug 3980'-3775' mud from 3775'-652' 10 sx. cement 652'-619' mud from 619'-33' 10 sx. 33'-0'
1	Permit to drill issued May, 1962. No other report filed with Railroad Commission Office. Field inspection revealed well had been drilled and plugged but no report or record of plugging was ever filed.					
2	Permit to drill issued May, 1962. No other report filed with Railroad Commission Office. Field inspection revealed well had been drilled and plugged but no report or record of plugging was ever filed.					
1	Abandoned unplugged oil well	294'	Drilling compl. 3/22/39	3004'	Top of pay 3000' Top of sand 3000' Perforation not recorded	----------
1	Dry plugged	---	11/11/60	3100'	------	50' plug from 2625' to 2575' 10 sx. at surface

Table IV-11 (cont.)

Well No.*	Type Well	Platform Elevation	Date Plugged	Total Depth	Formation Thickness	Plugging Data
3	Dry plugged	208'	5/25/52	3518'	Sand-3229'-3235' w/ small show of oil	75 sx. by Halliburton 8 sx. cement at bottom of surface pipe-102' 102' of 10-3/4" put in and left in
1	Abandoned unplugged oil well	289'	-------	2997' Woodbine Sand	Top of pay-2992'	Surface casing 8"-100' 4-1/2"-2992' 2"-2000'
1	Abandoned plugged gas well	---	1/14/71	11,700' Smack-over Form.	---------	100 sx. top 9030-bottom 9520' 100 sx. top 4101'-bottom 4319' 20 sx. top 489'-bottom 545' 10 sx. top 0'-bottom 20'
1	Dry plugged	290'	9/18/69	3426'	---------	40 sx. top 3145' bottom 3275' 35 sx. top 50' bottom 150' 5 sx. at surface 8-5/8"- 108'put in & left
1	Dry plugged	---	1/11/64	4331' Woodbine	---------	8-5/8"-266' put in & left 33 sx. cement from 4089'-3989' 33 sx. from 550' - 450' 35 sx. from 316' - 216' 5 sx. at top of surface
2	Dry plugged	---	6/13/62	8460'	---------	8-5/8"-772' put in & left 33 sx. from 7600'-7500' 33 sx. from 3650'-3500' 35 sx. 800'-700' welded plate on top surface casing

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CHAPTER V

ZOOLOGICAL ELEMENTS

by

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and

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TABLE OF CONTENTS

(Mammals & Birds)

(Fishes)

ZOOLOGICAL ELEMENTS - MAMMALS AND BIRDS

INTRODUCTION

In order to evaluate present environmental conditions in any designated geographical area or region, it is essential to have quantitative data pertaining to as many environmental parameters as possible. Such data also allow comparisons between sites or regions and serve as a basis for making predictions of future changes. Although avian and mammalian faunas are a small part of the total terrestrial animal population, they are of particular interest because of their economic and aesthetic values, and because of their widespread use as ecological indicators of environmental quality and change.

Owing to their relative conspicuousness and abundance, it is somewhat easier to gather quantitative data on birds than it is on mammals (or other kinds of terrestrial vertebrates). Birds also appear to be quite sensitive to quantitative and qualitative changes in the environment. Fluctuations in kinds or numbers of birds are often one of the first clues of *significant* alterations in the overall ecology of an area. It is therefore worthwhile to accurately describe and enumerate bird populations and to assign a high importance value to this biological parameter in any evaluation or model of environmental quality.

The purpose of this element of the study was to provide quantitative data on bird and mammal populations at ten different study areas along the Trinity River. Populations at these sites were compared with each other and were correlated with a quantitative estimate of habitat diversity at each site. Comparisons were also made between three arbitrarily designated river regions (upper, middle, and lower), and seasonal changes in population size and composition were documented. Finally, indices of species diversity were computed for both bird and mammal populations at each of the ten study areas, for each of the three river sections, and for the Trinity River as a whole.

MATERIALS AND METHODS

<u>Description of the Study Areas</u>

The general location of the ten study areas along the Trinity River are shown in Figure V-01. At each study area a 1,500 meter transect line (approximately one mile) was laid out and marked by surveyor's flagging tape every 15

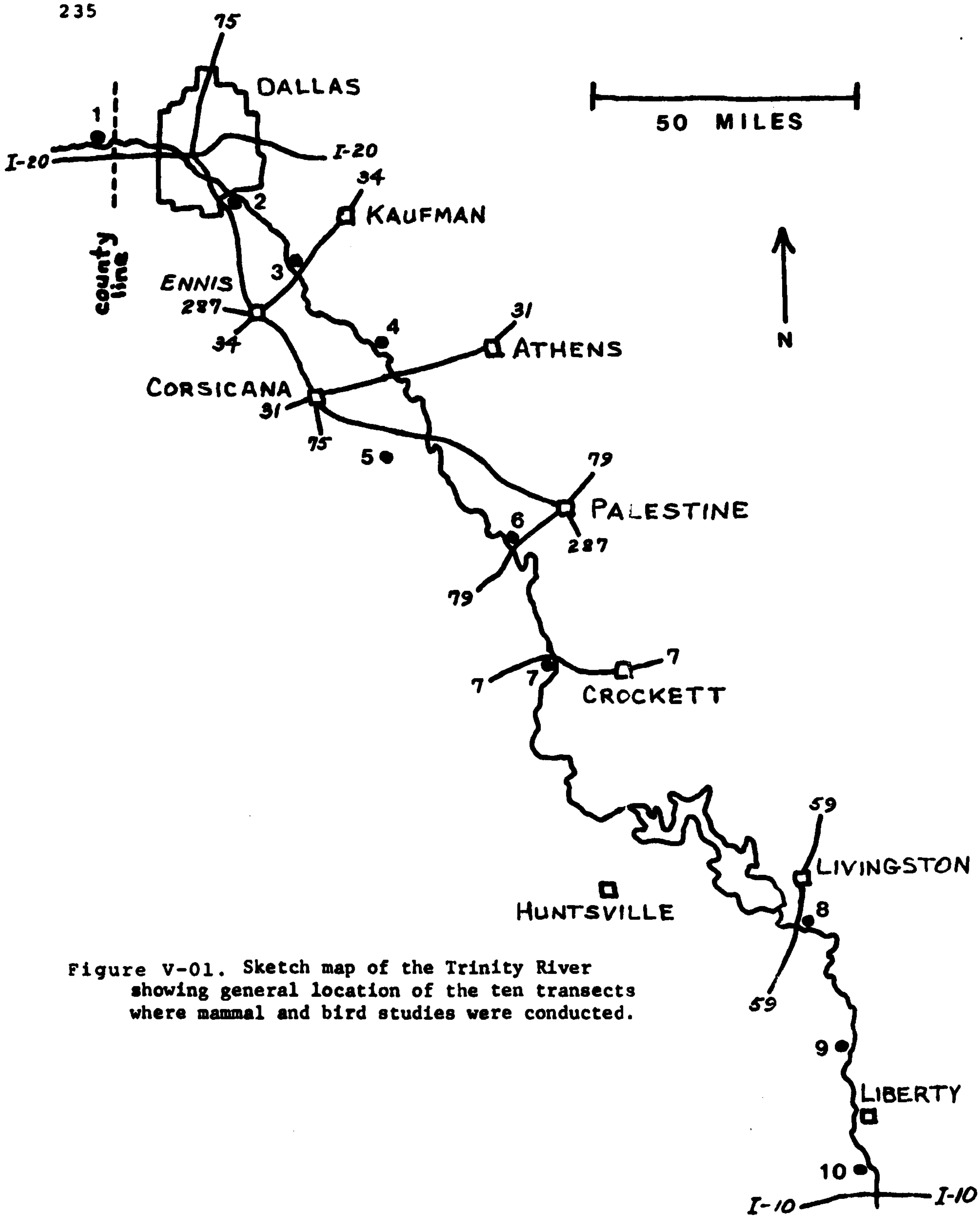

Figure V-01. Sketch map of the Trinity River showing general location of the ten transects where mammal and bird studies were conducted.

meters, thus creating 100 "stations" after the starting point. Distances were measured by pacing. The direction of a particular transect line varied because of artificial and natural topographic features, but an effort was made to avoid frequent or sharp turns. Each transect was usually set up to traverse more than one kind of habitat, though this policy was not always adhered to. A summary outline of each transect follows and Table V-01 describes the direction and habitats of each of the ten transects (see also Table V-02).

Transect No. 1

Location: extreme eastern Tarrant County, just south of the Greater Southwest International Airport, on the north side of the Trinity River and on the east side of Highway 360. Starting point: about 200 meters east of Highway 360 and 30 meters south of a railroad track. Habitat description: rather hilly topography; scrub oaks and scattered mesquite on upland sites; open cedar elm forests on the narrow river floodplain; large cottonwoods and willows along the river; frequent grassy or scrubby clearings. General comments: very heavy human use, principally motorbike riding and horseback riding; much noise disturbance from railroad trains and from airplanes landing and taking off at the airport; light livestock grazing by horses in the eastern part of the study area; frequent target shooting and "pot-shooting" along the river; the transect runs in a general eastward direction between the river (touching it at one point) and the main E-W railroad track.

Transect No. 2

Location: Dallas County, Fin and Feather Club on the southeast side of Dallas on the west side of the river just north of the Dowdy Ferry Road bridge. Starting point: north side of the Fin and Feather Club lake, about one mile north of the main clubhouse. Habitat description: open, heavily cutover floodplain forest dominated by cedar elms and oaks; many large cottonwoods were recently removed; frequent piles of brush; little ground cover; very homogeneous habitat. General comments: the transect parallels the river for most of its length, following rather closely a bulldozed track which lies between the river and a dike along the shore of the Fin and Feather Club lake; for the first ten stations the transect proceeds northerly toward the river, crossing the dike; the transect then turns right and follows the river downstream (touching the river bank

Table V-01. Summary description of Transects 1-10

Station No.	Compass Heading	General Habitat
	TRANSECT NO. 1	
1-10	115	dry woodland
10-20	"	wet thickets and grasses
20-30	"	wet woodland
30-50	090	wooded slope
50-58	165	thickets and forest edge
58-76	150	brushy field
76-100	150-170	thickets, grasslands, & forest edge
	TRANSECT NO. 2	
1-10	360	bottomland forest
10-100	NE, gradually curving to E and SE	"
	TRANSECT NO. 3	
1-30	320	forest edge
30-100	270	bottomland forest
	TRANSECT NO. 4	
1-12	180	forest edge
12-80	140	bottomland forest
80-89	050	"
89-100	320	"

TRANSECT NO. 5

1-13	105	transect winds back
13-25	325	and forth across a
25-29	240	narrowly-wooded
29-34	170	intermittent stream for
34-48	220	approximately the first
48-66	230	50 stations, then
66-67	300	follows along or
67-68	325	across grassy scrubby
68-77	240	pastures and cropland
77-83	250	
83-100	180	

TRANSECT NO. 6

1-10	340	old weedy bottomland field
10-20	"	bottomland forest
20-33	"	old weedy bottomland field
33-56	090	thickety fencerow
56-70	180	thickety fencerow
70-80	"	bottomland forest
80-100	"	old weedy bottomland field

TRANSECT NO. 7

1-3	135	woody slough
3-22	135	open scrubby thickets
22-41	135	bottomland forest
41-100	180 curving gradually to 210	bottomland forest

TRANSECT NO. 8

1-5	045	marsh
5-8	145	grazed pasture
8-14	135	grazed pasture
14-83	220	forest and forest edge
83-100	095	dense thickets and scrubby forest

TRANSECT NO. 9

1-30	190	mature bottomland forest
30-100	115	mature bottomland forest

TRANSECT NO. 10

1-22	020	old brush field
22-70	010	open bottomland forest
70-76	090	open grassy field
76-85	170	forest edge
85-100	145	open bottomland forest

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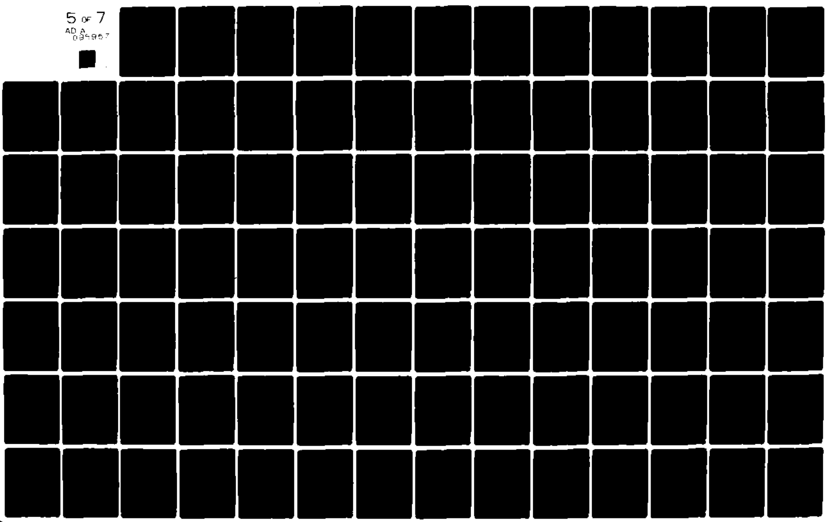


Table V-02. Summary of habitat types studied and habitat diversity indices at ten transects along the Trinity River

	Habitat Percentages													
	Transect Numbers										River Section[1]			Whole River
Habitat[2]	1	2	3	4	5	6	7	8	9	10	U	M	L	
Wd	30	95	78	85	25	15	65	25	90	60	68	47	58	58
Th	45	0	10	5	35	35	20	35	0	10	18	24	15	19
Gr	20	0	12	7	40	50	6	30	0	25	11	26	18	18
Aqu	5	5	0	3	0	0	9	10	10	5	3	3	9	5
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Habitat Diversity[3]	1.7	0.3	1.0	0.8	1.6	1.4	1.4	1.9	0.5	1.5	1.3	1.7	1.6	1.6

[1] Upper, middle, lower

[2] Wd: hardwood forests and woodlands; Th: thickets, scrub, and forest edge; Gr: grasslands, croplands, pastures, and weedy fields; Aqu: sloughs, swamps, marshes, ponds, and river edge.

[3] Computed using the Shannon-Wiener function (see text).

at two points), curving gradually almost 180° around to the right; there is no livestock grazing; during the open season squirrels and waterfowl are extensively hunted.

Transect No. 3

Location: Kaufman County, "Flying A" Ranch just west of Rosser on the east side of the river about 1 mile downriver from the mouth of the East Fork of the Trinity River. Starting point: top of the river levee about 1-1/2 miles west of a new ranch house owned by Fred Alford, Jr. The starting point lies on the levee about 300 meters NW of where a farm road climbs up on the levee. Habitat description: principally cedar-elm forest on the river floodplain; the first 30 stations follow the top of the levee, which is cleared and is grown up in grasses and weeds; large open fields and pastures lie within 100 meters of the northeast side of the levee (away from the river), although the levee itself on this side is bordered by a narrow strip of forest (about 75-100 meters wide); within the study area all of the land lying between the levee and the river (a rather wide area of about 1,200 meters) is forested. General comments: overall quality of the forest rather poor, but fairly good woody understory and grass ground cover; no livestock grazing during the duration of this study; scattered wet depressions and sloughs present on the floodplain; heavy black clay soil; no Spanish moss.

Transect No. 4

Location: Henderson County, Bruce Smith Ranch about nine miles northwest of Trinidad, approximately three miles upriver from the mouth of the outflow from Cedar Creek Reservoir. Starting point: about 50 meters from the river bank near a small hayshed where a vehicle track comes down to the river along a cleared strip through an extensively wooded area; there is a small clearing adjacent to the river bank at this site, which is the only non-forested area on the bank itself for several miles in either direction on this side of the river; just above the starting point the river makes a right angle bend from east to south, and then 3/4 of a mile downriver the river makes a wide bend to the left and flows in a northeasterly direction briefly before turning again, to the southeast. Habitat description: except for the small clearing at the beginning, the whole transect line traverses an extensive floodplain woodland dominated by cedar-elm. General comments: rather open forest with fairly mature trees (but no Spanish moss); many sloughs and wet depressions; heavy

grazing by cattle except when too wet; sticky black clay soil; the transect parallels the river for most of its length, touching the bank at one point.

Transect No. 5

Location: extreme northern Freestone County; Neal farm one mile south of the New Hope Church (on FM Road 416), approximately nine miles ENE of Streetman and 8-1/2 miles WSW of Highway 287 bridge over the Trinity River. Starting point: near a small intermittent stream about 100 meters west of the Neal trailer home; to get to the Neal farm go SSE on a gravel road which leads off FM 416 just east of the New Hope Church (there is a very short jog initially and another access to FM 416); in about 1/2 mile turn right (the gravel road continues on SSE) on another gravel road; this road will angle to the left (south) in less than 1/2 mile, and immediately thereafter the Neal trailer home will be on the right. Habitat description: upland farmland lying on a low rise between Tehuacana and Richland creeks (the study areas lies above the flood pool elevation of the proposed Tennessee Colony Reservoir); predominantly pastures and cropland; a narrow belt of cutover riverine woodland borders a small intermittent stream; scattered junipers in old neglected fields. General comments: banks of the intermittent stream rather steep in places; numerous small eroded gulleys along the upper portions of the stream; a few large mature trees (elm, pecan, hickory, and oak) remain in the woodland belt along the creek; scattered trees and thickets along the fencerows; all areas lightly to heavily grazed by cattle (except one large plowed field adjacent to the transect).

Transect No. 6

Location: Anderson County just north of Highway 79/84 bridge over the Trinity River, on the east side of the river approximately nine miles southwest of Palestine. Starting point: about 700 meters north of the highway and 250 meters east of the river, at a point in an old weedy field 150 meters south of a small (5 acre) isolated patch of forest on the river floodplain. Habitat description: old neglected, ungrazed weedy field and thickets on the river floodplain; two small isolated patches of cutover bottomland forest, each about 5 acres. General comments: this area has apparently had no human use for several years; presently there is no grazing and therefore a relatively good ground cover of grasses, vines, and *Rubus* exists (except in the two patches of forest where there is

very little ground cover); there is a narrow border of trees along some of the fences; the river itself (about 250 meters away) has a narrow belt of woodlands along the near bank; adjacent to the north side of the study area is a pasture heavily grazed by cattle; a small low wet marshy depression and drainage borders the transect area to the east.

Transect No. 7

Location: Leon County, just south of Highway 7 bridge over the Trinity River, on the west side of the river. Starting point: about 250 meters south of the highway and 500 meters west of the river, at a point on the north edge of a small woody slough. Habitat description: principally heavily cutover and grazed floodplain forest dominated by cedar elm; Spanish moss abundant; the forest at the beginning of the transect has been more heavily cleared and is now a scrubby clearing with scattered trees on a low rise in the topography between the slough and river floodplain; between the highway and the start of the transect is a small open heavily grazed pasture with a very small stock pond; an old weedy field borders this pasture to the west. General comments: the forest has only a few large trees and little ground cover; all of the study area is grazed by cattle; much *Crataegus* in the forest clearings; the transect in general parallels the river for most of the way, touching it at two points; several low wet depressions on the floodplain.

Transect No. 8

Location: southern Polk County; Jones farm on the north side of the Trinity River and east side of Highway 59. Starting point: about one mile east of Highway 59 and 1-1/2 miles north of the Trinity River, on the east side of McCardell's Lake at a point where a small intermittent stream leaves the lake. Habitat description: cutover woodlands mixed with open pastureland; a large swamp (McCardell's Lake) with some open water and many large tupelo gums borders the transect on the west; at the outlet of this swamp and for about 50 meters downstream (along the transect) is a small marshy area. General comments: all forests are heavily cutover with only a few scattered mature trees and sometimes with a dense thickety woody undergrowth; two cleared pipeline right-of-ways parallel or cross the transect line; all areas are heavily grazed by cattle.

Transect No. 9

Location: upper Liberty County, just south of Highway 162 bridge, about 50 meters from the river bank at a point approximately 100 meters south of a small stream flowing east into the river. Habitat description: mature cutover bottomland hardwood forest on the river floodplain; many scattered large mature oaks; bald cypresses numerous along the edge of a long slough. General comments: forest relatively open with little ground cover; at station 30 the transect line intersects a long water-filled slough bordered by cypresses, then turns left and parallels the near (to the river) edge of the slough for the rest of its length, finishing about 50 meters from the river bank; extremely heavy disturbance by wild pigs throughout the transect area but no cattle grazing during this study; by the end of the study a bulldozed track had been made into the area in preparation for a new housing development; shallow wet depressions and drainageways are common throughout the forest.

Transect No. 10

Location: extreme southern Liberty County, two miles east of the community of Old River (on FM Road 1409), just north of the Chambers County line and about two miles west of the Trinity River. Starting point: about two miles east of FM Road 1409 and 200 meters north of the east end of hard-surfaced road running east (parallel to the county line) from the community of Old River, at a point on a pipeline right-of-way. Habitat description: mostly open bottomland forest with much palmetto, and one large grassy neglected field; two large bayous bordered by cypresses; an open grassy scrubby upland area at the start of the transect (along and adjacent to the pipeline right-of-way). General comments: transect starts in an old field above the wide river floodplain but soon drops down onto the floodplain and runs in a northerly direction, parallelling the west bank of a prominent bayou; eventually the transect crosses this bayou (on an old small concrete bridge) and then shortly thereafter turns southward and runs between this bayou and another major bayou just to the east; all of the bottomland area is very heavily disturbed by wild pigs but no cattle were present during the study period; a good grassy ground cover was present in parts of the forest.

All habitats at every study area were classified into one of four major categories as shown in Table V-02. At each of the ten transects an estimate was made of the

percent contribution of each of the four major habitats to the total study area (study area being defined as that area within 150 meters of all points along the transect line). Habitat percentages were also calculated for each of three arbitrarily designated river sections defined as follows: upper river--transects 1, 2, and 3; middle river--transects 4, 5, 6, and 7; lower river--transects 8, 9, and 10.

Habitat diversity indices were calculated for each transect and river section, and for the river as a whole, using the Shannon-Wiener function:

$$H = -\sum_{i=1}^{s} \left(\frac{n_i}{n}\right) \left(\log \frac{n_i}{N}\right)$$

where "s" is the total kinds of habitats, "n_i" is the habitat percentage (expressed as a whole number) of each habitat, and N = 100 (since all habitat percentages add up to 100%). Although this is a very crude estimate of habitat diversity, it allows some statistical comparisons of other community parameters with habitat diversity.

Censusing Techniques

Biologists have usually found it difficult to obtain reliable estimates of population densities of terrestrial vertebrates. Various methods of censusing have been summarized for mammals in Giles (1971) and for birds by Emlen (1971). Frequently, however, it is not necessary to know absolute numbers or densities but simply to have available indices of abundance. Such indices, when determined by the same method, may be used in comparing populations either in space or time.

In the present study mammal populations were sampled in two ways. Small terrestrial mammals were caught in museum special snap traps set along the ten 1,500 meter transect lines. Peanut butter was used as bait and one trap was set at each station, 100 traps per night (with few exceptions). The number of trap stations in each of three major habitats at each transect is shown in Table V-03. Populations of larger mammals were sampled by counting all mammal signs encountered on a particular date by an observer while walking along a 1,500 meter transect. Separate counts were tabulated for: (a) individuals seen or heard, (b) sets of tracks, (c) fecal remains, (d) nests, dens, or burrows, and (e) food remains, gnawings, or diggings.

Table V-03. Number of trap stations in three general kinds of habitats at each of ten transects along the Trinity River

Habitat[1]	Transect Numbers 1	2	3	4	5	6	7	8	9	10	River Section U	M	L	Whole River
Wd	40	100	70	90	20	15	75	55	100	60	210	200	215	625
Th	25	0	30	10	45	40	25	30	0	15	55	120	45	220
[illegible]	35	0	0	0	35	45	0	15	0	25	35	80	40	155
TOTAL	100	100	100	100	100	100	100	100	100	100	300	400	300	1,000

[1] Notations are the same as in Table V-02.

Avian populations were estimated by recording all birds seen or heard by an observer walking slowly along or near each transect line, with occasional stops when groups of birds were encountered. Counts were always taken in the morning, beginning within an hour after sunrise, and were completed in 2-3 hours. Birds were counted when they were seen or heard flying over the transect line, whether they were actually utilizing or foraging in the study area itself or not. In addition to the transect counts a record was kept of all species found in or near each of the study areas, and regular counts of aquatic birds were taken at the Fin and Feather Club Lake adjacent to Transect No. 2 and at McCardell's Lake adjacent to Transect No. 8.

This study was carried out from September, 1972 through May, 1973. The general distribution and relative abundance of mammalian and avian populations along the Trinity River during the summer months (June and July) has been previously documented (Fisher, 1972).

RESULTS AND DISCUSSION

Small Mammals

Small mammal trapping successes at each of the ten transects are shown in Appendix V-01. Scientific names are from Blair, et al. (1968). These data, which are an index of relative abundance of small mammals, are summarized in Table V-04. The overall trapping success (2.8%) indicates that small mammals are not very abundant at most localities adjacent to the Trinity River. There is, however, considerable variation between sites and between different dates at the same site. Transect No. 6 had a much higher percent trapping success than any other transect. This is probably explained by the fact that this transect had the highest combined habitat percentages of thickets and grasslands (see Table V-02), and more importantly by the absence of livestock grazing at this site, which permitted a very good ground cover of grasses and vines. The cotton mouse (*Peromyscus gossypinus*) was by far the most abundant and widespread small mammal along the river, and this species together with the fulvous harvest mouse (*Reithrodontomys fulvescens*) made up 86% of the total population of small mammals at the ten study sites.

Trapping success in each of three major habitats (woodlands, thickets, and grasslands) is summarized in Table V-05. The percent success in each habitat on each night traps were set in that habitat, was compared to other

Table V-04. Summary of kinds and total numbers of small mammals caught in snap traps at ten 1,500 meter transects along the Trinity River from September, 1972 through May, 1973

Species	Transect Number 1	2	3	4	5	6	7	8	9	10	Total
short-tailed shrew								1			1
least shrew						1					1
hispid pocket mouse			1								1
fulvous harvest mouse			4			18	3	1		3	29
deer mouse				1		3	1				5
white-footed mouse			1								1
cotton mouse		1	6	19	1	23	8	1	7	3	69
pygmy mouse										1	1
cotton rat	1					3	1				5
eastern woodrat				1							1
Total individuals caught	1	1	12	21	1	48	13	3	7	7	114
Total traps set	450	300	393	300	500	400	500	380	465	350	4,038
Percent success	0.2	0.3	3.1	7.0	0.2	12	2.6	0.8	1.5	2.0	2.8
Total number of species	1	1	4	3	1	5	4	3	1	3	10

Table V-05. Summary of trapping success in each of three major habitat types at ten transects along the Trinity River

Transect Number	Wd caught	Wd set	Th caught	Th set	Gr caught	Gr set
1	1	200	0	105	0	145
2	1	300	-	-	-	-
3	7	263	5	130	-	-
4	18	270	3	30	-	-
5	0	100	1	225	0	175
6	8	60	20	160	20	180
7	10	375	3	125	-	-
8	2	210	1	110	0	60
9	7	465	-	-	-	-
10	3	180	3	75	1	95
TOTAL	57	2,423	36	960	21	655
% Success	2.4		3.8		3.2	
Sample size[2]	43		34		22	

[1] Notations are the same as in Table V-02.

[2] Number of different nights traps were set.

Table V-06. Summary of trapping success at ten transects along the Trinity River during the fall, winter and spring (1972-73)

Transect Number	Season: Fall caught	Fall set	Winter caught	Winter set	Spring caught	Spring set
1	0	100	1	200	0	150
2	-	-	0	100	1	200
3	0	60	8	200	4	133
4	17	200			4	100
5	0	100	0	600	1	200
6	5	100	10	600	33	200
7	8	200	1	100	4	200
8	1	100	1	100	1	180
9	0	165	0	100	7	200
10	-	-	2	200	5	150
TOTAL	31	1,025	23	1,300	60	1,713
% Success	3.0		1.8		3.5	
Sample size[2]	11		13		19	

[1] See text for definitions.

[2] Number of different nights traps were set.

Habitats by a t-test. The equation used is:

$$t = \frac{(\bar{X}_1 - \bar{X}_2)\sqrt{\frac{N_1 N_2}{N_1 + N_2}}}{\sqrt{\frac{(N_1-1)S_1^2 + (N_2-1)S_2^2}{N_1 + N_2 - 2}}}$$

where $\bar{X}$ is the sample mean, s^2 is the sample variance, and N is the sample size. There were no statistical differences (at the .05 level of probability) in percent trapping success between any two habitat types.

A comparison of trapping success was also conducted between the three seasons of the year during which the study was carried out (Table V-06). Fall is defined as the months of September, October, and November; winter as the months of December, January, and February; and spring as the months of March, April, and May. There were no statistically significant differences in seasonal trapping success.

Comparisons of trapping success between each pair of transects were also made, using t-tests in the same manner as above (sample sizes were quite small, ranging from 3 to 5). These calculations show that Transects 1 and 5 which have very low populations, are statistically different from Transects 3, 4, 6, and 7 (at the .05 level of probability). Transects 1 and 5 are the most upland in topography of all the ten study sites. However, both have considerable human disturbance, which may help explain the relatively low abundance of small mammals at these sites.

Finally, t-tests were used to compare each pair of the three arbitrarily defined river sections. Sample sizes were 13 for the upper and lower rivers, and 17 for the middle river. Trapping success was 1.2% for the upper river, 4.9% for the middle river, and 1.4% for the lower river. There are no statistically significant differences between any two river sections.

Simple linear correlation and regression analyses were run using the total percent trapping success as the dependent variable. The transect number and habitat diversity index (Table V-02) were both used, separately as independent variables. The regression of trapping success versus transect number had a correlation coefficient of .057, and trapping success versus habitat diversity had a correlation coefficient of -.043, neither of which is

significant at the .05 level of probability (with 8 degrees of freedom). These tests indicate that total numbers of small mammals along the Trinity River are not directly correlated with habitat diversity (as here measured) and that there is no gradual increase or decrease in numbers of small mammals from one end of the river to the other.

Larger Mammals

Data gathered on larger mammals at each of the ten transects are presented in Appendix V-02, and a summary is given in Table V-07 (note that the eastern woodrat appears both in these tables and those for small mammals). Scientific names are from Blair, et al. (1968). Because of the many variables involved in gathering these data (such as weather conditions at the time of and prior to the census, density of foliage, ground cover, soil type, etc.) they must be interpreted cautiously. Nevertheless, the data reflect the relative abundance of larger mammals in the areas studied. It is apparent that such species as the armadillo, swamp rabbit, fox (and/or gray) squirrel, coyote (and/or domestic dogs), and raccoon are abundant and widespread along the Trinity River. Only at the most upland site (Transect No. 5) do cottontails appear to be as numerous as swamp rabbits. Cottontails prefer drier habitats than the swamp rabbit (Davis, 1966). White-tailed deer were much more numerous along the middle river (Transects 4, 5, 6, and 7) than along either the upper or lower river.

Populations of larger mammals at each of the ten transects were compared with one another by t-tests of the total number of all mammal signs recorded on each census. These total numbers were each considered an index of population size on a specific data at a particular transect. Sample sizes (number of censuses at each transect) ranged from three to five. Results of these t-tests are shown in Table V-08. There are significant differences in the numbers of larger mammals at different sites along the Trinity River. A possible explanation for the low population sizes at Transects 9 and 10 is the very high numbers of wild pigs in the study areas. It is more difficult to postulate reasons for the relatively low number of larger mammals at Transect 8. When the three river sections were each compared with one another the lower river was statistically different (at the .01 level of probability) from both the upper and middle river sections, but these two latter sections were not significantly different from each other.

Table V-07. Total numbers of larger mammals and mammal signs recorded on 40 censuses at ten 1,500 meter transects along the Trinity River from September, 1972 through May, 1973

	Transect Number										
	1	2	3	4	5	6	7	8	9	10	Total
opossum	4	3	9	3		1	5	1	2	1	29
eastern mole					1						1
armadillo	66	16	74	48	44	23	64	27	8	21	391
swamp rabbit	23	53	34	32	7	22	73	16	20	9	289
cottontail rabbit	8		14	3	7	8	6	4		2	52
gray squirrel									1	1	2
fox squirrel	6	3	8	10				2		2	31
(fox and/or gray squirrel)	11	52	42	15	15	15	32	13	12	17	224
flying squirrel	8					4					12
plains pocket gopher					31						31
beaver	4	10	40	16			1		1		72
eastern woodrat			3	3					5	1	12
nutria	1	3						7			11
coyote	4	4	19	6	4	2	3	2	1		45
(coyote and/or dog)	15	13	35	10	17	19	15	22	7	9	162
gray fox	5	2	2	1			2		1	1	14
raccoon	19	11	23	30	10	14	22	17	16	7	169
mink				1							1
striped skunk	3		14	2	1	4	3		2	3	32
bobcat			2	1							3
white-tailed deer			4	61	65	29	21	5	6	4	195
Total number	177	170	323	242	202	141	247	116	82	78	1,778
Number of censuses	4	3	5	4	4	4	4	4	4	4	40
Average no. Per census	44.2	56.7	64.6	60.5	50.5	35.2	61.8	29.0	20.5	19.5	44.4
Total number of species	12	9	13	14	9	10	11	9	11	12	19

Table V-08. Values of t[1] for paired comparisons of population size[2] of larger mammals at ten Trinity River transects

Transect Number	2	3	4	5	6	7	8	9	10
1	2.59*	1.64	3.53*	0.71	0.95	2.60*	2.83*	7.46**	7.90**
2		[illegible]	0.72	0.59	2.31	0.65	4.41**	10.11**	10.59**
3			0.33	1.00	2.03	0.22	2.80*	3.63**	3.72**
4				1.11	3.13*	0.18	5.50**	10.75**	11.16**
5					1.23	1.09	2.27	3.56*	3.69*
6						2.75*	1.08	2.60*	2.76*
7							4.34**	6.69**	6.89**
8								1.82	2.05
9									0.63

[1] An asterisk indicates statistical significance at the .05 level of probability, and two asterisks indicate significance at the .01 level.

[2] Total number of all mammal signs on each census.

The average number per census of all larger mammals and signs (Table V-07) was used as the dependent variable and regressed, separately, against transect number and habitat diversity as for small mammals. The correlation coefficient of -.230 in the latter instance is not statistically significant, suggesting once again that habitat diversity per se is not as important as other factors in determining abundance of mammal populations. The correlation coefficient of -.709 obtained in the former analysis is significant, however, at the .05 level of probability (with 8 degrees of freedom). This correlation results primarily from the relatively small numbers of mammal signs at the three transects (8, 9, and 10) at the lower end of the river. When the average number per census of larger mammals and signs was regressed against the total percent trapping success (of small mammals) there was no significant correlation. Apparently population sizes of larger mammals and small mammals are independent of each other.

All Mammals

In order to calculate a species diversity index for all mammals at each transect, an effort was made to combine the relative abundance data for both small and larger mammal populations, recognizing the problems involved because of the different sampling methods utilized and different kinds of signs recorded. It was decided that each n in the Shannon-Wiener function would be best indicated by the highest number recorded from all the censuses at a given transect. For small mammals this figure is the highest number trapped on any single night. Total number trapped on all censuses could have been used, since individuals trapped were removed from the population, but it was felt this would have biased the index in favor of small mammals. For larger mammals the figure used was the highest number of all the signs recorded. Gnawings, diggings, and evidence of food remains were excluded for all species except the semi-aquatic beaver and nutria. This was done in an effort to reduce bias in favor of certain species (such as the armadillo) in which some individuals occasionally leave an unusually large amount of sign. Only fresh beaver gnawings were recorded. The difficulty of trying to equate mammal tracks and fecal remains and nests and individuals seen or trapped as indicators of relative abundance is acknowledged. Relative to larger mammals, populations of small mammals are probably underestimated. Species diversity indices computed using these data are given in Table V-09.

Table V-09. Species diversity of terrestrial mammal populations at ten transects along the Trinity River

Species[1]	Transect Number 1	2	3	4	5	6	7	8	9	10
*opossum	2	2	3	2		1	2	1	2	1
*eastern mole					1					
short-tailed shrew								1		
least shrew						1				
*armadillo	7	3	9	7	6	3	7	4	2	2
*swamp rabbit	7	18	7	8	3	7	27	6	5	2
*cottontail rabbit	4		2	2	2	4	2	4	1	2
*gray squirrel[2]									3	3
*fox squirrel[2]	6	5	11	6	7	6	8	5		5
*flying squirrel	3					3				
*plains pocket gopher					12					
hispid pocket mouse			1							
*beaver	1	4	4	1			1		1	
fulvous harvest mouse			3			11	2	1		3
deer moust				1		1	1			
white-footed mouse			1							
cotton mouse		1	3	13	1	15	4	1	5	2
pygmy mouse										1
cotton rat	1					1	1			

Table V-09 (cont.)

Species[1]	Transect Number 1	2	3	4	5	6	7	8	9	10
*eastern woodrat			2	1					2	1
*nutria	1	2						4		
*coyote[3]	3	3	7	3	3	4	4	4	3	3
*gray fox	2	1	2	1			1		1	1
*raccoon	7	7	9	12	4	6	11	8	5	3
*mink				1						
*striped skunk	2		7	1	1	2	2		1	2
*bobcat			1	1						
*white-tailed deer			2	11	21	8	12	2	4	3
TOTAL	46	46	74	71	63	71	87	38	34	34
Number of species	13	10	17	16	11	15	15	12	12	15
Species diversity index[4]	3.4	2.7	3.7	3.4	2.9	3.4	3.2	3.2	3.4	3.8

[1] No asterisk indicates the numbers in the row are the highest number trapped on any one night; an asterisk indicates the numbers are the highest number of all signs recorded on all censuses (except see text).

[2] Each number in Appendix V-02 recorded as "fox and/or gray squirrel" is considered here as fox squirrel.

[3] Half of each number in Appendix V-02 recorded as "coyote and/or dog" is considered here as coyote (the other half was omitted from consideration).

[4] Computed using the Shannon-Wiener function (see text).

If the transects in Table V-09 are grouped by river section and the numbers for each species are added together in each section, then these sums can be used as n_i's to compute a species diversity index for each river section. Similarly, figures from all ten transects can be added together for each species and these sums used to calculate a species diversity index for the river as a whole. Each transect is thus considered a different sample from the whole "population", and the highest number recorded for each species from all censuses at each sampling locality is considered to be the best index of relative abundance of that species at that locality. Following are the species diversity indices calculated in this manner (total number of species are in parentheses): upper river, 3.63 (20); middle river, 3.60(22); lower river, 3.80 (18); whole river, 3.85 (28). It is apparent that species diversity of terrestrial mammals is virtually the same on all three river sections and that the river as a whole has about the same diversity as any single section. Furthermore, differences between the ten transects (Table V-09) do not seem very great, though index values tend to be somewhat lower for individual transects than for a whole river section or the total river.

Since diversity indices are receiving widespread attention in ecological investigations it is worthwhile to consider what factors influence their values. Krebs (1972) has summarized (in Ch. 23) much of the current thinking and history pertaining to diversity indices. Theoretical considerations are discussed by Fisher, Corbet, and Williams (1943), Lloyd and Ghelardi (1964), MacArthur (1957), Margalef (1958), Pielou (1966), Preston (1948), and Williams (1953). In regard to the Shannon-Wiener function used to compute diversity indices in this study, it has been shown by Lloyd and Ghelardi (1964) that only two factors influence index values: number of species and equatability of distribution (i.e., relative abundance). The other factor remaining constant, species diversity can be increased only by: (1) increasing the number of species, or (2) changing the relative abundance so that rare species become commoner and common species become rarer. The maximum possible diversity index for a given number of species (s) is realized when all species are equally abundant, in which case the diversity index (computed by the Shannon-Wiener function) = log S. The actual population size in the community being measured does not directly influence species diversity (i.e., other factors remaining constant an increase or decrease in overall population size will not change the species diversity

index). Customarily diversity indices are computed for a specific taxonomic group of organisms in an arbitrarily chosen "community" or habitat. It could be argued that the ten transects in the present study are not equivalent "communities", and therefore cannot be compared.

It is beyond the scope of this report to critically evaluate the numerous attempts by various workers to relate species diversity indices to other ecological parameters, such as community stability, community maturity, community structure, habitat diversity, etc. The interested reader is directed to papers by Connell and Orias (1964), Elton (1958), Hairston (1959), MacArthur (1955), MacArthur and MacArthur (1961), MacArthur, Recher, and Cody (1966), Margalef (1963, 1968, and 1969), and Odum (1969).

In the present study of mammal populations several ecological parameters at each of the ten Trinity River transects were compared with one another by the use of simple linear regression analyses in order to look for possible correlations within communities and to perhaps gain insight into community organization. The tests run (with the dependent variable being mentioned first) were: (1) species diversity vs. Habitat diversity, (2) species diversity vs. Transect number, (3) species diversity vs. Average number per census of all larger mammals and signs (used here as an index of total population size), (4) species diversity vs. Total percent trapping success (as an index of total population size of small mammals), (5) number of species (all mammals) vs. Habitat diversity, and (6) number of species vs. Transect number. None of the computed correlation coefficients proved to be statistically significant (at the .05 level of probability). Thus it is concluded that the ecological parameters tested here are not directly related, or at least that their relationship is relatively unimportant (multiple regression analyses would help answer this question). There is no unidirectional trend in mammal species diversity or variety along the Trinity River, and species diversity appears to be influenced more by factors other than habitat diversity or population size. It is suggested that environmental "quality" is probably an important contributing factor to species diversity, and could perhaps be measured in part by careful quantitative analyses of vegetational characteristics (see MacArthur and MacArthur, 1961 in regard to bird species diversity and physical characteristics of the vegetation).

Transect Studies of Birds

Results of each census at all ten transects are shown in Appendix V-03 and these data are summarized in Appendix V-04. Scientific and common names follow those of the A.O.U. (1957) and the A.O.U. Committee On Classification And Nomenclature (1973). During this study a total of 196 species of birds were recorded on 59 censuses at the ten Trinity River transects, and an additional 31 species were recorded from the study areas during non-census periods. It should be emphasized that these investigations occurred primarily during the non-breeding part of the year for birds, and the data obtained are therefore not an indication of the breeding avifaunal populations. A general account of breeding birds and their relative abundance along the Trinity River is given by Fisher (1972). However, it would be worthwhile to carry out during the breeding season (June, July, and August) a quantitative investigation similar to the present one.

Like the majority of animal species, most birds are closely associated with a particular kind of habitat. Therefore, the absence of some kinds of birds, particularly those of aquatic or semi-aquatic environments, from a particular transect does not necessarily indicate that these species were absent from that general area of the Trinity River, but may have resulted simply from the lack of a suitable "niche" at the site of the transect. Forest and woodland environments were sampled most thoroughly, and aquatic habitats and grasslands least completely (see Table V-02). Ideally a separate transect should be set up in each major habitat at every study area along the river, but the time limit imposed on the present research did not permit such a detailed investigation. However, quantitative data pertaining to the use of the Trinity River by aquatic birds were gathered regularly at small lakes adjacent to Transects 2 and 8, and these will be presented later in this report, as will other observations of waterfowl and of small wading birds.

Inspection of Appendix V-04 reveals that many avian species are widespread along the whole length of the Trinity River. These include the little blue heron, cattle egret, turkey vulture, red-tailed hawk, killdeer, mourning dove, barred owl, chimney swift, ruby-throated hummingbird, four species of woodpeckers, great crested flycatcher, eastern phoebe, barn swallow, blue jay, common crow, and a large number of small "songbirds" (chickadee, titmouse, creeper, wrens, thrushes, kinglets, vireos, warblers,

"blackbirds", buntings, sparrows, etc.). Some species, on the other hand, were confined to a particular segment of the river. The Swainson's hawk, rough-legged hawk, Franklin's gull, black-chinned hummingbird, ladder-backed woodpecker, western kingbird, and great-tailed grackle were found only on the upper parts of the river; the barn owl, white-tailed kite, and Smith's longspur were recorded only on the middle river; and the anhinga, white ibis, hooded warbler, Brewer's blackbird, and Swainson's warbler were observed during this study only on the lower half of the river. It is noteworthy that a pair of white-tailed kites built a nest at Transect 7, since this represents the northernmost breeding record of this species in the state, and is well north (and east) of the present known range of the white-tailed kite in Texas (see Wolfe, 1956). Among the most abundant species were the blue jay, common crow, Carolina chickadee, tufted titmouse, Carolina wren, robin, starling (locally), redwinged blackbird, common grackle, brown-headed cowbird, cardinal, myrtle warbler, and white-throated sparrow. The redwinged blackbird was by far the single most numerous avian species.

Population sizes of birds were compared by t-tests. Each census was considered an estimate of population size (see the "total individuals" figures for each date in Appendix V-03). Values of t were calculated for the following paired comparisons: (1) each of the ten transects was compared with every other transect, using data from all censuses (sample sizes ranged from 5 to 7); (2) each of the three river sections was compared with the other two sections, using data from all censuses (sample sizes were 17, 23, and 19 for the upper, middle, and lower rivers, respectively); (3) using data from the whole river, each of the three seasons was compared with the other two (sample sizes were 13, 20, and 26, respectively); (4) for each of the three seasons a comparison was made between the upper and middle river sections (sample sizes ranged from 3 to 9), upper and lower river sections (sample sizes ranged from 3 to 9), and middle and lower river sections (sample sizes ranged from 4 to 9); and (5) for each of the three river sections a comparison was made between the fall and winter (sample sizes ranged from 3 to 8), fall and spring (sample sizes ranged from 3 to 9), and winter and spring (sample sizes ranged from 6 to 9). Average population sizes for each transect are given in Appendix V-03, and are summarized by river section and season in Table V-10.

Table V-10. Summary of bird distribution, diversity, and abundance along the Trinity River during the non-breeding season (fall, winter, and spring)

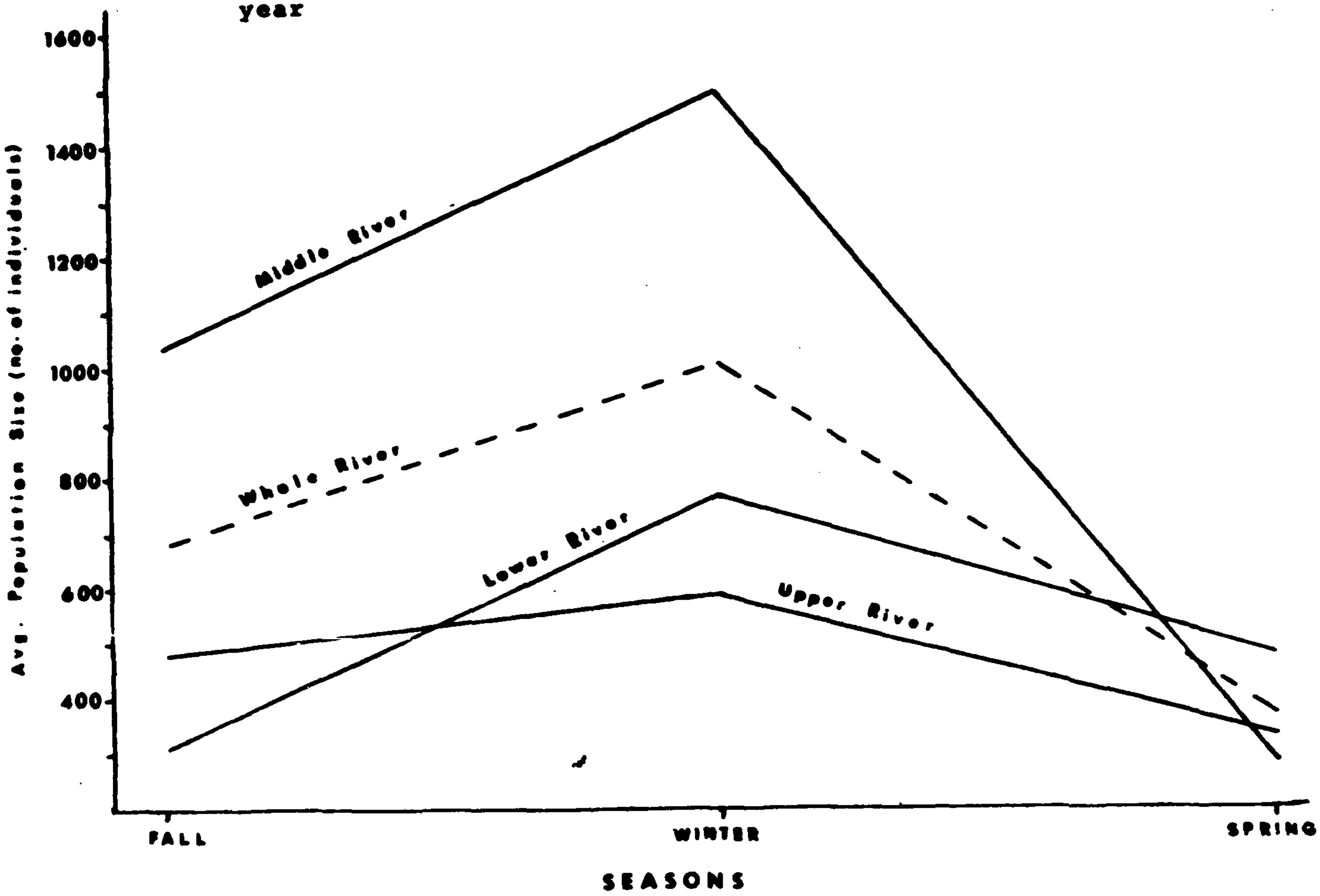
Season	Upper River No. Of Species	Upper River Average Pop.Size	Middle River No. Of Species	Middle River Average Pop.Size	Lower River No. Of Species	Lower River Average Pop.Size	Whole River No. Of Species	Whole River Average Pop.Size
Fall	66	483	78	1,041	97	310	136	688
Winter	60	590	76	1,501	83	768	102	1,008
Spring	111	339	116	287	120	474	169	363
TOTAL	131	453	145	906	148	532	196	655
diversity index[1]	5.4		3.8		5.5		5.1	

[1] Computed using the Shannon-Wiener function (see text).

None of the ten transects were statistically different in population size (at the .05 level of probability) from any of the other transects. This is somewhat surprising because of the rather large differences in average population size and would appear to be explained by the very large variances in population size at individual transects and by the rather small sample sizes. Transect 6 with an average population size of 1,486 individuals (on 6 censuses), and Transect 4, with an average population size of 1,002 individuals (on 5 censuses), had by far the largest average population sizes of the ten transects. At both these transects the unusually large population sizes were due principally to a single species, the redwinged blackbird. This species is well known for its enormous winter concentrations in the southern United States, and often occurs in huge flocks with other icterids and starlings (i.e., "blackbirds" in a general sense). It should be pointed out that usually the large flocks of redwinged blackbirds counted were observed flying overhead, without stopping, although occasionally they were seen foraging in the study area. Other gregarious species which were sometimes seen in large numbers were the double-crested cormorant and white ibis (both at Transect 10, flying overhead), robin, starling, common grackle, and brown-headed cowbird. Large aggregations of "blackbirds" are responsible for the unusually high population sizes on the middle river in the fall and winter, and also account for the relatively high Winter population on the river as a whole (Table V-10).

Of the t-tests carried out with population sizes at different seasons and river sections, only six were statistically different (at the .05 level of probability). These were: (1) winter vs. spring on the upper river, (2) winter vs. spring on the middle river, (3) fall vs. spring on the middle river, (4) fall vs. spring on the river as a whole, (5) winter vs. spring on the river as a whole, and (6) middle river vs. lower river in the spring. Conclusions which can be drawn from these tests are: (a) on the upper river, middle river, and river as a whole winter populations were significantly higher than spring populations (but not on the lower river, where spring populations were relatively high); (b) on the middle river and the river as a whole winter populations were also significantly higher than fall populations; and c) spring populations on the lower river were significantly higher than on the middle river. Trends in average population size from fall to winter to spring are shown in Figure V-02.

Figure V-02. Seasonal variation in average population size of birds along the Trinity River during the non-breeding period of the year

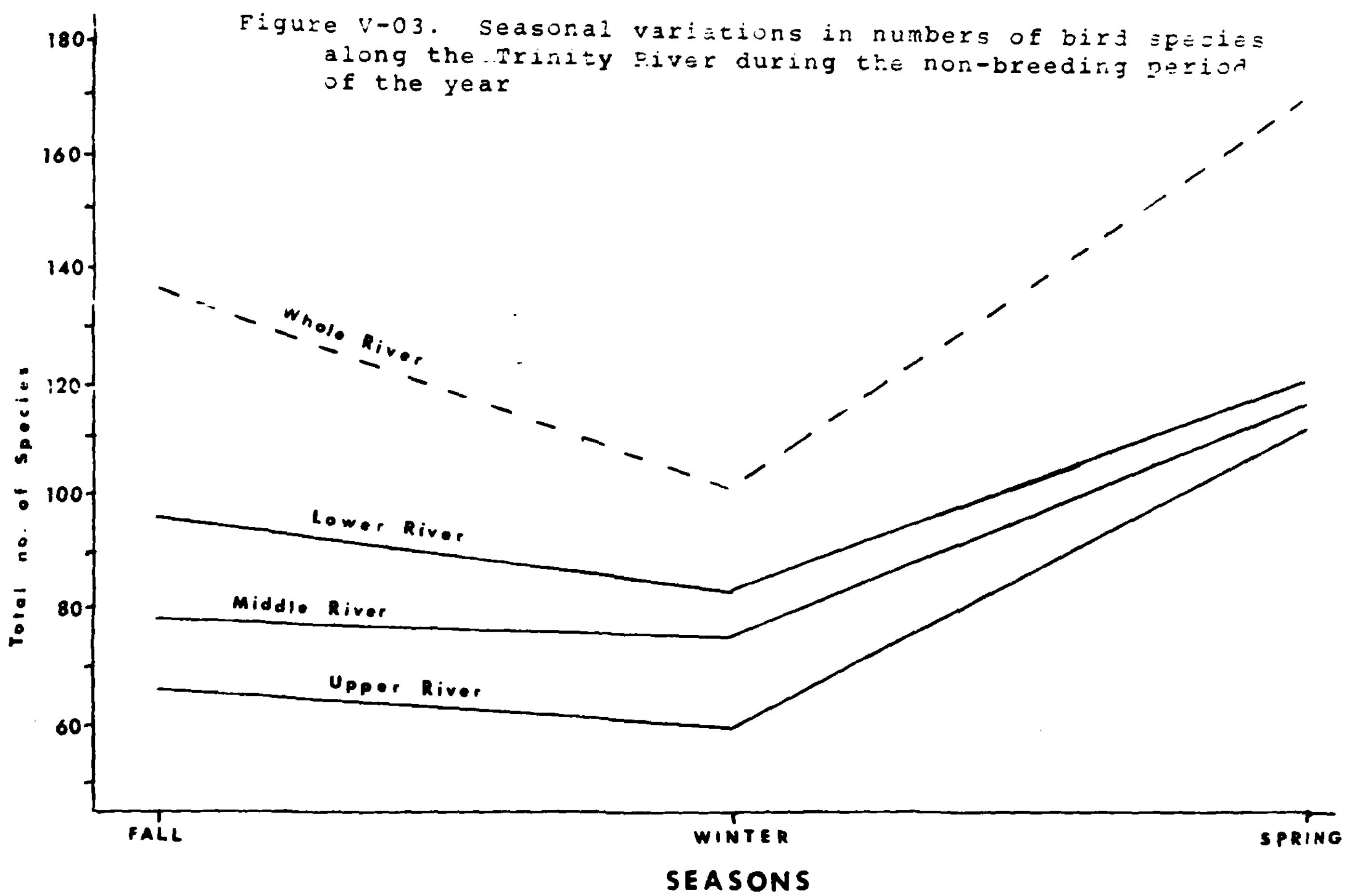


Note that in every instance winter populations were the highest, and everywhere except on the lower river spring populations were the lowest (see also Table V-10). It is of interest that all the significant differences in population size (except one) are related to seasonal factors rather than to river section, in spite of the much larger numbers recorded on the middle river during the fall and winter.

Fluctuations in variety of Trinity River birds (i.e., number of species present) are shown in Figure V-03 and Table V-10. On all three river sections and the river as a whole the number of bird species recorded was lowest in the winter and highest in the spring. This trend is exactly the reverse of that for average population size. In the winter birds were present in greatest numbers but least variety, while in the spring they were present in greatest variety but fewest numbers. Such changes in the avifauna along the Trinity River are the result of the annual spring and fall migrations of birds. Differences in species variety were not tested statistically, but it is noteworthy that in all three seasons variety of birds was greatest on the lower river and least on the upper river. Transect 8 had the greatest variety of species (120), and the fewest number of species was recorded at Transect 2 (70). It will be shown later that these differences are correlated with habitat diversity.

The Shannon-Wiener function was used to compute species diversity indices for each of the ten transects, for each of the three river sections, and for the river as a whole. The maximum number of individuals counted on any single census (Appendix V-04) was used to represent abundance (n_i) of each species; all the n_i's were then summed to get N. It is felt that the maximum individual count from all censuses conducted at a particular transect is a better estimate of real abundance of a particular species than an average number of individuals from all three censuses. However, it would be worthwhile, although not done here, to compare diversity indices computed by using these two slightly different methods for obtaining values of n_i. It would not have been feasible to use the sum of recorded figures from all censuses at a particular transect because of the probability of counting some individuals more than once, since individuals counted were not collected. In calculating diversity indices for a particular river section the maximum counts from each of the appropriate transects were added together for each species and their sum used for n_i. Similarly, maximum counts from all ten transects were summed to obtain each n_i

Figure V-03. Seasonal variations in numbers of bird species along the Trinity River during the non-breeding period of the year



when computing a diversity index for the river as a whole. It should be noted that diversity indices computed for birds from data gathered during this study are indices for non-breeding populations, which were continually fluctuating in size and species composition.

Diversity indices for all ten transects are given in Appendix V-04, and indices for the three river sections and the whole river are shown in Table V-10. The two factors influencing diversity indices (number of species and equitability) have already been discussed. The importance of diversity indices in ecological studies lies in their use as indicators of environmental quality (see Wilhm and Dorris, 1968), and in their possible correlation with such parameters as community stability, community maturity, community structure, community change, community metabolism, and food webs (see references cited previously). The values calculated in this study will be tested below, by simple linear regression analyses, with certain other data gathered in the current investigation.

The following simple linear regressions were performed (the dependent variable is mentioned first; all analyses have 10 data points and 8 degrees of freedom; a correlation coefficient of .632 or higher is statistically significant at the .05 level of probability): (1) bird species diversity vs habitat diversity, transect number, average population size of birds, and mammal species diversity (2) number of bird species vs habitat diversity, transect number, and number of mammal species; and (3) average population size of birds vs habitat diversity, transect number, percent trapping success of small mammals, and average number of larger mammals and signs.

Only three of these 11 regression analyses had relatively high correlation coefficients. Interestingly, the highest correlation (r=.951) was between the average population size of birds and the total percent trapping success of small mammals. This correlation exists primarily because Transects 4 and 6 had much higher totals of both small mammals and birds than any other transects (Appendices V-01 and V-03). At both of these transects the cotton mouse and the redwinged blackbird were clearly dominant. The remarkable correlation between small mammals and birds along the Trinity River is thus primarily a result of the fact that redwinged blackbirds and cotton mice were both most numerous at Transect 6 (principally an old weedy bottomland field) and were both next most abundant at Transect 4 (a rather mature open bottomland

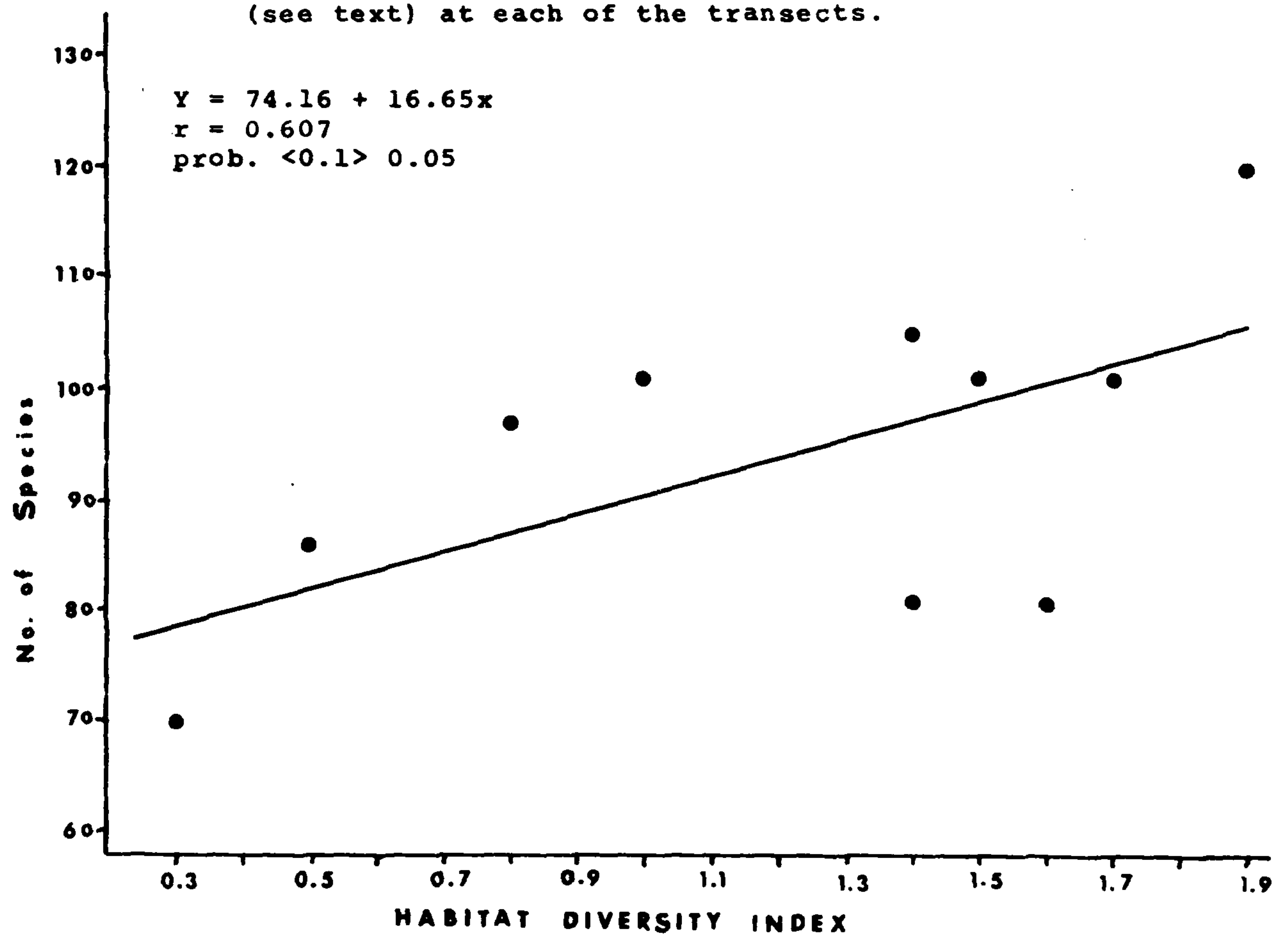
forest dominated by cedar elm). Two habitats could hardly be more different, at least superficially. It is therefore difficult to postulate what factors in the environment, if any, resulted in the positive correlation between population sizes of birds and small mammals.

Average population size of birds when regressed against bird species diversity resulted in a correlation coefficient of -.816. That is, as the average population size of birds increased, species diversity of birds decreased. There is no a priori reason why this should be true. The answer appears to lie in the fact that the highest bird populations were those at Transects 4 and 6, where numbers of a single species (the redwinged blackbird) greatly exceeded numbers of all other species, sometimes accounting for more than half the total avian population on a given date. The tremendous abundance of a single species greatly changes the "equitability" of species distribution (see Lloyd and Ghelardi, 1964). As common species get commoner (like redwinged blackbirds in the present study), diversity indices decrease in value. This would seem to explain the negative correlation here between population size and species diversity.

Because of the specific habitat preferences of most kinds of birds, it would be predicted that species variety would increase as habitat diversity increased. The positive correlation (r=.607) between these two variables in the present study is therefore not surprising (though this correlation coefficient is not quite statistically significant at the .05 level of probability). This regression line is shown in Figure V-04. Interestingly, although number of species increased with habitat diversity, there was no increase in bird species diversity with habitat diversity. This appears to result from the fact that even though number of species influences species diversity, in this study of bird populations there was no significant correlation between these two variables. It would seem that equitability was the more important component of the Shannon-Wiener function, rather than number of species. Equitability in bird populations was apparently not closely correlated with habitat diversity.

There was no unidirectional trend in avian populations along the Trinity River in population size, species variety, or species diversity. Population size was not correlated with habitat diversity, suggesting that bird populations were approximately the same density in different kinds of habitats. When bird populations were

Figure V-04. Total number of census species at each of ten Trinity River transects regressed against the diversity (see text) at each of the transects.



compared with mammal populations there were no significant correlations of species diversity, species variety, or population sizes (with the one exception, already discussed, that bird and small mammal population sizes were positively correlated). Apparently in most instances the factors influencing diversity, variety, and size of bird and mammal populations are not the same.

Non-transect Studies of Birds

A limited amount of data on avian populations were gathered from observations other than transect censuses. These pertained primarily to wading and aquatic birds. Counts were taken on six different dates at the Fin and Feather Club Lake adjacent to Transect 2 (Table V-11), and on ten different dates at McCardell's Lake adjacent to Transect 8 (Table V-12). The abundance and variety of waterfowl and other aquatic species at these two lakes are probably typical of that at most of the swamps, sloughs, and oxbow lakes along the whole length of the Trinity River. As indicated in Table V-12 there is a large aggregation of nesting herons, egrets, and ibises at McCardell's Lake. Nesting sites preferred by the smaller herons and egrets were principally buttonbush, whereas the great blue heron and great egret preferred tupelo gums growing in the middle of the swamp. Additional studies are presently being undertaken in regard to these nesting birds and their interrelationships with the vegetation and water quality in the swamp.

Both of the above two lakes are approximately one mile long and roughly 100-200 acres in area, but they are very different in vegetational structure. The Fin and Feather Club Lake is primarily an open body of water with a marshy upper end. A dike runs across the middle of the lake and along the east and south sides between the lake and the river. Water is supplied to the lake primarily from Trinity River overflow once every two or three years. Normally there is no water flowing through the lake. McCardell's Lake, on the other hand, is a natural swamp with very little open water. Woody vegetation grows almost everywhere, and there are relatively extensive areas of pure tupelo gum. There is a very small marshy area at the lower end where water leaves the lake via a small stream. A low amount of water flowed from the lake throughout this

Table V-11. Numbers of individuals[1] of shore and aquatic birds recorded from the Fin and Feather Club lake adjacent to Transect 2

	Dates (1972-1973)					
Species[2]	Sept.30	Feb.20	Feb.24	Mar.25	Apr.7	Apr.27
pied-billed grebe*		3		2	1	5
double-crested cormorant			2	560	37	1
little blue heron	6					
great egret	12					
snowy egret	1					
mallard		16		2		
gadwall		225				
pintail		285	65			
green-winged teal		325	30			
blue-winged teal*			17	11	30	3
shoveler			3		3	
wood duck*						2
ring-necked duck		25	77			
canvasback			3			
lesser scaup			3			
ruddy duck			7			
osprey						1
American coot*	1	300	120	95	35	16
ring-billed gull				4		
Franklin's gull					1	5

[1]Counts were made during a 30-60 minute period by an observer walking across the E-W dike in the middle of the lake.

[2]Asterisks denote probable breeding species.

Table V-12. Numbers of individuals[1] of shore and aquatic birds recorded from McCardell's Lake adjacent to Transect 8

Species[2]	Oct. 21	Nov. 17	Dec. 9	Jan. 3	Feb. 14	Mar. 11	Mar. 23	Apr. 1	Apr. 29	May 28
					Dates (1972-1973)					
pied-billed grebe*	3		2				1	2		
double crested cormorant					14	1		2		
anhinga*	1				2	4	8	57	72	86
great blue heron*			1	3	36	41	35	93	84	62
green heron*									2	12
little blue heron*	1					72	30	281	360	660
cattle egret*	32	42		1		16	4	146	617	1815
great egret*					35	66	75	103	114	110
snowy egret*						1	1	6	11	7
Louisiana heron								1		
black-cr night heron								1		
yellow-cr night heron*						31	43	33	25	43
white ibis*	1						1	112	448	18
snow/blue goose	4									
mallard	1	5	22	14	34	2	5	3		
gadwall			24	13	23	15	18	3		
pintail			4							
green-winged teal	3		12	23	17		5	2		
blue-winged teal	1					12	50	24	14	
American wigeon	7	10	30	32	42	45	3			
northern shoveler	1	1	3			4				
wood duck*	25	8	16		22	12	19	7	2	9
ring-necked duck			2							
sora rail								1		

Table V-12 (cont.)

purple gallinule*									2	4
common gallinule*	3					1			3	2
American coot*	3		7		25	5			15	1
killdeer*	6	12	11	14	2					2
common snipe	19	2	6							
solitary sandpiper							1	2	4	
belted kingfisher*	1	1			1		1			

[1]Counts were usually made over a period of approximately two hours just before dusk by a single observer at the lower (east) end of the lake; on May 28 there were four observers, each at a separate observation point around the lake, and on October 21 observations from the upper end of the lake are also included; observations were made from a canoe on February 14.

[2]Asterisks denote probable breeding species.

investigation, but the source of water entering the swamp was not determined.

On February 10 and 11, observations of birds were made from a boat along an eight mile stretch of the Trinity River from the Highway 162 bridge at Transect 9 downriver to the outlet of "Mud Lake", and on the lake itself. Mud Lake is a narrow, shallow, wooded, floodplain lake about 3/4 of a mile long, through which Tanner Bayou and Little Bayou drain into the river. It is bordered by large cypresses and has many cypresses growing in the shallow upper end of the lake. Aquatic and wading birds recorded are given in Table V-13. Of particular interest is the large number of great egrets and great blue herons which were foraging on the sandbars and mudflats along the river, and the more than 150 ducks on Mud Lake. These data, along with those previously presented indicate that the small lakes, swamps and sloughs on the Trinity River floodplain are utilized fairly extensively by waterfowl during the winter months and early spring.

On September 29,1972, observations were made near Transect 3 of birds migrating south immediately following a brief, heavy rainstorm which preceded a well-defined cold front moving into the area from the northwest. Birds were flying very high, mostly singly, taking advantage of very high winds at that level. Species identified are shown in Table V-14. Noteworthy are the large flocks of pelicans and the wide variety of hawks, including a single peregrine falcon (possibly two). On the following morning a flock of 140 wood storks was recorded flying to the south over Transect 3.

Small wading birds ("shorebirds") were not often seen on transect censuses since suitable habitat was usually lacking. That these species utilize the Trinity River valley as a migration route, however, is indicated by observations on May 12,1973, in a wet field adjacent to Transect 3 on the river floodplain. Heavy rains the night before accounted for several pools of standing water in the field, a grassy pasture heavily grazed by cattle. In a two hour period of observation over 300 individuals of 20 different kinds of shorebirds were counted (Table V-15).

During this study three species of birds currently considered rare or endangered were recorded along the Trinity River : the bald eagle (2 birds at Transect 4, see Appendix V-03), peregrine falcon (1 or 2 birds near Transect 3, see Table V-14), and osprey (1 bird at the Fin and Feather Club Lake, see Table V-11). In addition to

Table V-13. Shore and aquatic birds recorded on February 10 and 11, 1973 at Mud Lake and along an eight mile stretch of the Trinity River, both near Transect 9

Species	Number o Individuals[1] River Shore	Mud Lake
double-crested cormorant	1	
anhinga	2	1
great blue heron	24	3
great egret	82	
mallard		60
green-winged teal		65
wood duck	6	50
spotted sandpiper	5	
belted kingfisher	2	

[1]Counts were made by an observer in a bo t, during a one-hour period in late afternoon at Mud Lake and during a 45 minute period in the morning on the river (from the Highway 162 bridge downriver to the Mud ake outlet).

Table V-14. Birds recorded from near Transect 3 on September 29,1972 flying south very high in the air immediately following the passage of a rainstorm preceding a well-defined cold front[1]

Species	Number
white pelican	1,300[2]
double-crested cormorant	178[3]
great blue heron	6
turkey vulture	1
sharp-shinned hawk	7
Cooper's hawk	4
(*Accipiter* sp.)	6
Swainson's hawk	7
broad-winged hawk	12
marsh hawk	3
peregrine falcon	1
American kestrel	21
(large falcon sp.)	1
(small falcon sp.)	9
(small "shorebirds" sp.)	13[4]
Franklin's gull	1

[1] Birds were counted by two observers for a two hour period, and were seen singly except as indicated.

[2] In four flocks of 280,500, 250, and 290 birds each.

[3] Two flocks of 160 and 18 birds each.

[4] Single flock.

Table V-15. Small wading birds (charadriiformes) recorded from a 50-acre wet field adjacent to Transect 3 on May 12, 1973[1]

Species	Number
semipalmated plover	1
piping plover	1
killdeer	14
whimbrel	2
upland sandpiper	23
spotted sandpiper	6
willet	2
greater yellowlegs	1
lesser yellowlegs	10
pectoral sandpiper	150
white-rumped sandpiper	13
Baird's sandpiper	2
least sandpiper	11
semipalmated sandpiper	40
dunlin	1
long-billed dowitcher	3
stilt sandpiper	15
buff-breasted sandpiper	8
Hudsonian godwit	5
Wilson's phalarope	35
TOTAL INDIVIDUALS	343

Total species: 20

[1] Counts were made by a single observer during a two hour period in the morning.

these records, two adult bald eagles were seen together on February 17, 1973, in Leon County between Transects 6 and 7, at a point approximately 3 miles west of the river, flying toward the river in the general direction of Stanmire and Clear Lakes. These three species are probably regular migrants and winter visitants, in very small numbers, along the Trinity River. The more remote parts of the river and the less disturbed lakes and swamps are undoubtedly used for foraging, as are artificial reservoirs such as Cedar Creek Reservoir and Lake Livingston.

SUMMARY

Mammal and bird populations were regularly censused, during the period September, 1972 through May, 1973, at ten 1,500 meter transects situated along the Trinity River. Estimates of population sizes were made by the following methods: (1) for small mammals by the number of animals caught in snap traps set every 15 meters along each transect, (2) for larger mammals by the number of individuals seen or heard and the number of signs (tracks, feces, nests, diggings, etc.) recorded by an observer while walking along each transect, and (3) for birds by the number of individuals seen or heard by an observer while walking along each transect during a 2-3 hour period in the morning.

The environment of each transect was classified into four major categories: woodlands, thickets and edge, grasslands and fields, and aquatic habitats. A crude index of habitat diversity was calculated for each transect using the Shannon-Wiener function. For the river as a whole, the ten study areas were composed of 58% woodlands, 19% thickets and edge, 18% grasslands and fields, and 5% sloughs, swamps, ponds, and river. All areas were moderately to heavily disturbed by past or present human activities, principally livestock grazing and timber removal.

Species diversity indices were calculated, using the Shannon-Wiener function, for both mammal and bird populations at each transect, and also for three arbitrarily defined river sections (upper, middle, and lower) and the river as a whole. Population sizes were compared statistically by the use of a t-test, and simple linear regression analyses were used to test for the presence or absence of statistical correlations between such parameters as species diversity, habitat diversity, species variety, population size, and transect number.

Twenty-eight species of mammals and 227 species of birds were recorded from the ten study areas during this investigation. The most widespread and abundant mammals were the cotton mouse, armadillo, swamp rabbit, fox and/or gray squirrel, coyote, raccoon, and white-tailed deer (the latter principally on the middle river). Cotton mice constituted more than half of the total small mammal population, and this species together with the harvest mouse made up 86% of all mammals trapped.

There were many widespread species of birds, and only a relatively few were confined to a particular river section. Certain birds typical of central and west Texas, however, were recorded only on the upper river, a region where such species as the white ibis, anhinga, hooded warbler, and Swainson's warbler were absent. The red-winged blackbird was by far the most numerous avian species, but other very common birds were the blue jay, common crow, Carolina chickadee, tufted titmouse, Carolina wren, robin, starling (locally), common grackle, brown-headed cowbird, cardinal, and white-throated sparrow. Waterfowl occurred in moderate numbers on a small open artificial lake adjacent to Transect 2, and on a small swamp adjacent to Transect 8. Herons and egrets bred in very large numbers at the latter site.

The overall trapping success of 2.8% indicates that in general small mammals were not very common in the ten study areas. Small mammals were least abundant at the two most upland transects (1 and 5) and most abundant at Transects 6 (an old neglected field on the floodplain) and 4 (a relatively mature bottomland forest dominated by cedar elm). There were no statistically significant differences in trapping success between woodland, thicket, or grassland habitats, or between any of the three river sections (though trapping success was somewhat higher on the middle river) or the three seasons. Population sizes of larger mammals often differed significantly, but most noteworthy were the much smaller populations at Transects 8, 9, and 10 on the lower river (which resulted in populations of larger mammals being negatively correlated with transect number). It is suggested that the large number of wild pigs at the latter two sites may be a major factor in the reduced populations of larger mammals in those areas. Population sizes of larger mammals and small mammals were not correlated.

Population sizes of birds ranged from 169 to 3,401 individuals per census. There was considerable variation

between dates at a particular transect, so that statistically population sizes between any two pairs of transects were not significantly different. Nevertheless, the highest populations were at Transects 4 and 6 where redwinged blackbirds were most numerous, and during the fall and winter bird populations were much higher on the middle river than elsewhere.

At all three seasons bird species variety was greatest on the lower river and least on the upper river. On all three river sections, and on the river as a whole, the variety of bird species was greatest in the spring and lowest in the winter, but the average size of the total avifaunal population was highest in the winter and was lowest in the spring (except on the lower river). Thus winter was the time of highest individual numbers of birds but the lowest variety, and spring was the time of greatest variety but lowest number of individuals.

There were no unidirectional trends along the Trinity River in population size, species variety, or species diversity of either birds or mammals. The single exception was that large mammal populations were smaller on the lower river than elsewhere.

When mammal populations were compared with bird populations there were no significant correlations of species diversity or species variety, suggesting that the factors which influence these parameters in mammals are not the same as those for birds. Bird and small mammal population sizes were positively correlated.

Variety of birds was positively correlated with habitat diversity, but mammal variety was not. Bird species diversity was negatively correlated with average population size, apparently because as certain avian populations increased due to large flocks of redwinged blackbirds the equitability of these populations declined, lowering diversity index values. Neither bird nor mammal species diversity were correlated with habitat diversity. This suggests that environmental "quality" may be more important in influencing species diversity of these animals than is variety of habitat per se.

No rare or endangered mammals were recorded during this study. Three species of rare or endangered birds were seen: bald eagle, osprey, and peregrine falcon. These three species are probably regular migrants and winter residents along the Trinity River, in very small numbers.

ZOOLOGICAL ELEMENTS - FISHES

INTRODUCTION

In a previous report submitted to the U. S. Army Corps of Engineers (Hall, 1972) the occurrence of 84 fish species in the Trinity River drainage system was documented. Species were listed on the basis of numerous field collections, newspaper reports, published documents, unpublished Texas Parks and Wildlife Department Dingell-Johnson research reports and personal communication with commercial fishermen along the Trinity River.

No attempt was made in the previous study to enumerate or discuss at length the myriad of ecological factors operating on and within fish populations in the drainage system. Baseline data regarding the fish species present and their distribution within the system were obtained in order that a framework of reference could be established for the present study.

Since the completion of the report mentioned above, numerous additional Trinity River fish species records have been called to this investigator's attention by Clark Hubbs, John V. Conner And Mark Kelly, all of whom have collected extensively within the drainage system. No treatise, as such, has dealt exclusively with the fishes of the Trinity River system to date and additional species, no doubt, await discovery within the sprawling system. The additional species records added by the individuals above are listed in the "Results" section of this report.

Completion of the inventory of fishes in the system was one of the major objectives of this phase of the study and with the inclusion of the additional species the overall status of fish populations within the river is somewhat clearer. It should be emphasized, however, that the inventory is not yet complete. The numerous "marine invaders" listed by Conner (personal communication) in the "Study Areas" section of this report attest to the ever-changing conditions in the lower river. Increases and decreases in salinity due to flow volume determine to a large extent the number of marine species likely to be found in the lower river at any given time.

The 130 fish species and hybrids presently documented for the Trinity River compares well with the reports of: Moore and Paden (1950) who listed a total of 92 fish species from the Illinois River; Luce (1933) who found 89

species in the Kaskaskia River, Illinois; Rozenburg, *et al.* (1972) who collected 56 species in the Navasota River, Texas; Martin and Campbell (1953) who listed 68 fishes from the Black River, Missouri; and Banarescu (1961) who found 83 fish species in the Danube River of Europe. These river systems, with the exception of the Danube, are unlike the Trinity in that they do not flow directly into a marine body of water. The greater number of species from the Trinity is due, largely, to the influx of numerous brackish water and marine species in the lower zone of the river.

It is a general rule that the number of fish species increases from the source(s) to the mouth of the river, as has been established in western and eastern Europe (Huet, 1954, 1959; Backiel, 1964), South America (Kleerekoper, 1955), and North America (Hallam, 1959; Larimore and Smith, 1963; Rozenburg, *et al.*, 1972). This trend has also been documented for the Trinity River. Mark Kelly (personal communication) has documented the occurrence of 55 extant species in the headwaters as compared to approximately 125 species for the mid- and lower reaches of the system. Some overlap of ubiquitous species occurs, hence the totals above reflect the occurrence of some species in all three zones (headwaters, mid-river, and lower river) and are used only as comparative rather than absolute numbers of species for each zone.

Thompson and Hunt (1930) noted that there is a more or less linear relationship between the logarithm of the drainage area upstream from a collecting station and the number of fish species occurring there. It has also been confirmed by Müller (1955a), Hallam (1959), Tesch and Albrecht (1961), and Larimore and Smith (1963) that the total number of individuals of all species per unit area declines in a downstream direction. Thus, there are fewer fishes per square meter (or per cubic meter) of water as one proceeds downstream, although the individuals are usually larger and the total weight per unit area remains more or less constant.

The basic assumptions underlying most of the above "rules" are that (1) the river system has not been significantly modified from its natural state by the activities of man (e.g., introduction of pollutants, silt, pesticides, etc.) And (2) that no obstructions are present in the river system which impede or prevent the migrations and other normal movements of fishes. Neither of the above assumptions holds true for the Trinity River. The upper segment of the river is polluted by various domestic and

industrial wastes from the Dallas-Fort Worth metroplex area (as well as from other cities within the basin) and Lake Livingston Dam currently obstructs and completely prevents movement of fishes above river mile 128 on the lower river.

Another major objective of this phase of the study was to examine certain selected ecological parameters which influence presently existing fish populations in the river. Eighteen species of rough, game, and forage fishes were arbitrarily selected for "Profile Analysis" in regard to: habitat preference, reproductive habits, food habits, economic value, specialized adaptations, and possible effects of canalization and impoundment upon their population densities. It should be stressed that the last item is largely speculative and depends to great extent upon canal and reservoir design, as well as fisheries management techniques which may be employed in the future. These 18 species were selected primarily upon the basis of their relative abundance, their importance in the Trinity River aquatic food chain, and their sport and/or commercial value.

Some of the ecological factors influencing fish populations which will be considered herein include: current velocity, mean water depth, shoreline development, bottom substrates, fecundity, dissolved solids, storage ratios of reservoirs, age of the impoundment, and water level fluctuation. Jenkins (1964, 1968, 1970) has reported on the effects of many of these environmental variables in his surveys of artificial impoundments in the South and Southwestern United States (including several Texas reservoirs, though none were within the Trinity River basin). In addition, Hynes (1970) dealt with various aspects of river ecology which directly or indirectly influence fish populations.

MATERIALS AND METHODS

Field studies were initiated on this phase of the Trinity River Project during October, 1972 and were completed during early May, 1973. Ten widely separated sampling stations were established from the upper reaches of the river near Fort Worth, Texas downstream to near the mouth of the Trinity River at Trinity Bay. These sites (previously described, Chapter I) were selected on the basis of their ecological uniqueness, location, habitat diversity, or other important features.

Little field work was accomplished during this phase of the study because of: (1) excessive rainfall in the watershed throughout the study period which resulted in extremely high water levels in the river; (2) an extremely cold winter marked by several snows (3) an unaccountable delay by the Texas Parks and Wildlife Department in granting a renewal of a scientific collecting permit for fishes ; and (4) refusal of the Texas Parks and Wildlife Department to issue an electrofishing permit for this study.

During the limited periods during which field collections could be made fishes were collected with: common sense minnow seines (1/4 and 3/8 inch mesh sizes), drag seines, gill nets, and hoop nets. Fishes were preserved in the field in 10% formalin and later, in the lab were sorted, identified, cataloged, and placed in fresh 10% formalin.

Creel census data were also obtained by direct conversation with fishermen and by examination, with their permission, of their catch. Data were recorded on a mimeographed "Creel Census Data Sheet" (Appendix V-05). These were found to be of limited value due to the lack of angling during the extended periods of high water.

A 16 foot Monarch DW flat bottom Jon boat and 20 hp. Chrysler outboard motor were used for reconnaissance and collecting trips on the river.

Air and water temperatures were obtained during each collection, as well as data regarding aquatic vegetation, bottom type, water depth, flow velocity, method of capture, turbidity, dissolved oxygen, pH, and detergents. These data were recorded in the field on prepared data sheets (Appendix V-06).

Taxonomic keys and checklists used for identification of fishes collected during this survey included: Moore (1968), Hubbs (1970, 1972), Eddy (1957), Smith-Vaniz (1968), and Parker, et al. (1971).

The common name listed for a fish species in this report is that which has been selected and approved by the American Fisheries Society's Committee on Names of Fishes as published by Bailey, et al. (1970).

Unpublished data regarding fish species in the Trinity River and their distribution within the system have been

contributed by John V. Conner, Clark Hubbs, and Mark Kelly.

STUDY AREAS

Additional Species Records

In this seven-month study 7033 fishes were collected which represented 9 families, 13 genera and 19 species. A previous five-year study by Lamb (1957) documented the occurrence of 57 species within the Trinity River system. Hall (1972) expanded the list to 84 species. Species records recently obtained from Clark Hubbs (personal communication) have resulted in the inclusion of 12 additional species (Table V-16). Data supplied by Mark Kelly (personal communication) have added 4 additional species (Table V-16) for the system. In addition, Conner's data have resulted in the inclusion of 28 additional species and hybrids, most of which are "marine invaders" of the lower Trinity River. Kelly and Conner also listed several species whose status in the system is in doubt for one reason or another. The "questionable species" are listed separately in Table V-17.

In addition to the 44 newly-documented species by Hubbs, Kelly, and Conner, 2 additional species have been added by our field work during this phase of the project (one of these, the black buffalo, was also listed by Conner). These two species are also listed in Table V-16.

One additional species record has been found in the literature. Dendy and Scott (1953) listed the southern brook lamprey from this system.

All totaled there are, at present, 130 documented fish species for the Trinity River system. For the most part these are ubiquitous and apparently no endemic, rare, or endangered species occur within the system (Conner, personal communication; Miller, 1971).

According to Conner (1973) the Trinity River per se forms a range boundary for very few fish species. Apparently only two species, the emerald shiner and the creek chub, have the Trinity as their western limit. He notes that the Trinity, however, does seem to limit the eastern distribution of several species such as the stoneroller, chub shiner, silverband shiner, sand shiner, plains killifish, Mississippi silverside, and orangethroat darter. Most of these appear to be restricted to the upper portions of the Trinity River, i.e., above the coastal plain.

Table V-16. Additional fish species and hybrids reported from the Trinity River drainage system[1]

Family	Common Name[2]	Source
Petromyzonidae	southern brook lamprey	Dendy and Scott, 1953
Carcharhinidae	bull shark (marine invader)	Conner, 1973
Dasyatidae	Atlantic stingray (marine invader)	Conner, 1973
Elopidae	ladyfish (marine invader)	Conner, 1973 and Clark Hubbs (pers. Comm.)
Ophichthidae	speckled worm eel (marine invader)	Conner, 1973
Clupeidae	finescale menhaden (marine invader)	Hall, original
Cyprinidae	speckled chub	Clark Hubbs (pers. Commn)
	pallid shiner	Conner, 1973 and Clark Hubbs (pers. Comm.)
	ghost shiner	Conner, 1973 and Clark Hubbs (pers. Comm.)
	emerald shiner	Conner, 1973
	chub shiner	Conner, 1973
	Sabine shiner	Conner, 1973
	red shiner x blacktail shiner hybrid	Conner, 1973

	creek chub	Conner, 1973 and Mark Kelly (pers. Comm.)
Catostomidae	western creek chubsucker	Conner, 1973
	black buffalo	Hall, original and Conner, 1973
	blue sucker	Clark Hubbs (pers. Comm.)
Ariidae	sea catfish (marine invader)	Conner, 1973
Belonidae	Atlantic needlefish (marine invader)	Conner, 1973 and Clark Hubbs (pers. Comm.)
Cyprinodontidae	plains killifish	Conner, 1973 and Mark Kelly (pers. Comm.)
	Rainwater killifish (mainly estuarine)	Conner, 1973 and Clark Hubbs (pers. Comm.)
	Diamond killifish (mainly estuarine)	Clark Hubbs (pers. Comm.)
	Saltmarsh topminnow (mainly estuarine)	Clark Hubbs (pers. Comm.)
Atherinidae	Mississippi silverside	Conner, 1973 and Mark Kelly (pers. Comm.)
	Rough silverside (marine invader)	Conner, 1973
Syngnathidae	Gulf pipefish (mainly estuarine)	Conner, 1973
Centrarchidae	green sunfish x bluegill sunfish hybrid	Conner, 1973
	green sunfish x redear sunfish hybrid	Conner, 1973
Percidae	orangethroat darter	Conner, 1973 and Mark Kelly (pers. Comm.)

	goldstripe darter	Conner, 1973 and Clark Hubbs (pers. Comm.)
	Cypress darter	Conner, 1973 and Clark Hubbs (pers. Comm.)
Sparidae	pinfish (marine invader)	Conner, 1973
Sciaenidae	sand seatrout (marine invader)	Conner, 1973
	spotted seatrout (marine invader)	Conner, 1973
	spot (marine invader)	Conner, 1973
	black drum (marine invader)	Conner, 1973
	red drum (marine invader)	Conner, 1973
Mugilidae	mountain mullet (marine invader)	Conner, 1973
	white mullet (marine invader)	Conner, 1973
Eleotridae	fat sleeper (marine invader)	Conner, 1973 and Clark Hubbs (pers. Comm.)
Gobiidae	darter goby (mainly estuarine)	Conner, 1973
	freshwater goby (mainly estuarine)	Conner, 1973
	naked goby (mainly estuarine)	Conner, 1973
Bothidae	bay whiff	Conner, 1973
Soleidae	lined sole	Conner, 1973
	hogchoker	Conner, 1973
Cynoglossidae	blackcheek tonguefish (marine invader)	Conner, 1973

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[1] In addition to those previously reported by Hall (1972)
[2] Scientific names are listed in Appendix V-07.

Table V-17. Questionable fish species reported from the Trinity River system [1]

Family	Common Name [2]	Source
Lepisosteidae	shortnose gar	Lamb, 1957
Acipenseridae	shovelnose sturgeon	Baughman, 1950
Polyodontidae	paddlefish	McCune, 1971
Characidae	Mexican tetra	Kelly, pers. Comm.
Cyprinidae	goldfish Plains minnow	Kelly, pers. Comm. Lamb, 1957
Ictaluridae	stonecat	Fowler, 1945
Centrarchidae	rock bass	Kelly, pers. Comm.
Cichlidae	Mozambique mouthbrooder	Conner, 1973

[1] Doubtful records because of failure of original stock in establishing breeding populations or because of doubt regarding the validity of reports listing the species as occurring in the system.

[2] Scientific names are listed in Appendix V-07.

The taxonomic relationship between the Mississippi silverside and the tidewater silverside presents an enigmatic problem which is currently under investigation by several workers. Apparently both species, if in fact they are separate species, do exist in the Trinity River system. In addition, there are populations which show a mosaic of morphological features, thus indicating that hybridization may be occurring between the two groups or that they may, in fact, be conspecific with a great deal of morphological variation existing between various populations.

To further complicate matters the transitional zone between fresh and saltwater, i.e., the estuary at and near the mouth of the Trinity River, harbors many fish species which may be temporary or, in some cases, long-term inhabitants of the lower river. Seasonal fluctuations in river flow, salinity, turbidity, dissolved solids, dissolved oxygen, etc., unquestionably influence the movement of many of the brackish-water and marine species upstream and freshwater species downstream.

Questionable records of fish species from the Trinity River system are listed in Table V-17. Certain of the species such as the paddlefish and the pallid shiner were, no doubt, once present but have apparently disappeared within recent years (Hall, 1972; Conner, 1973). Others such as the stonecat and the shortnose gar have apparently been included as a part of the Trinity ichthyofauna by mistake (Fowler, 1945; Lamb, 1957). Still other species such as the Mexican tetra and the goldfish have been stocked either intentionally or unintentionally.

Recently introduced non-native game fish species in the Trinity River watershed are listed in Table V-18. The striped bass is now found in approximately the lower two-thirds of the system while the walleye has been stocked in Garza-Little Elm Reservoir near Dallas, Texas.

Criteria sometimes used for the inclusion of fish species in an inventory checklist, i.e., that a reproducing, self-sustaining, well-established population must be evident, are not followed herein. The presence of any fish species in the Trinity River system, as documented by any valid method, is deemed sufficient for inclusion in this survey.

Fisheries Research Data

Most of the data presented in the following section have been obtained by the investigator and associates by the use of seines and gill nets during the limited periods

Table V-18. Non-native introduced game fish species in the Trinity River system

Family	Common Name	Source
Serranidae	striped bass[1]	Carpenter, 1972
Percidae	walleye[2]	Kelly, pers. Comm.

[1] Stocked in Lakes Bardwell and Navarro Mills originally and now found in Lake Livingston and the Trinity River.

[2] Stocked in Garza-Little Elm Reservoir near Dallas, Texas.

of accessibility to the river. Data included in Tables V-19 and V-20 however, were provided by Texas Parks and Wildlife Department personnel headquartered at Sheldon Reservoir near Houston, Texas and were obtained by the use of electrofishing gear.

Attention is called to the fact that weights in the two tables mentioned above are expressed in pounds, whereas in all other tables the unit of weight used is the gram.

No attempt will be made herein to correlate data with specific station sites as previously established for this study. Several of the stations were impossible to sample during this study because of complicating factors mentioned earlier. In addition, the dispersal of fishes during high water also makes quantification and estimation of population sizes untenable. The only absolute methods for obtaining complete data on fishes per unit area or unit volume of water are to: (1) drain the body of water and collect all fishes or, (2) kill all fishes in the area by some method. Neither of these methods was feasible during this study.

Table V-19 based on electrofishing samples taken July 12, September 13, and December 6, 1972 at the Texas State Highway 21 bridge reveals the condition of the Trinity River fish populations at or near its confluence with Lake Livingston. Eighteen fish species were present, most of which are well-adapted to lake-type environments which is *prima facie* evidence of lake influence upstream to this point. Of the 387 individuals taken at this station only 56, 14.48%, were game fish. In total weight, however, the game fish comprised 55.65% of the overall total; thus indicating that the individual game fish, on the average, were much larger than the coarse or non-game individuals.

Table V-20 presents data which are somewhat enigmatic in that the number of species (20) taken at the Trinity River bridge on Texas State Highway 19 exceeds the number of species taken further upstream and out of Lake Livingston proper, as listed in Table V-19. Lake stations usually possess fewer species than stream or river stations, but that was not true in this instance. The total number of individuals taken also exceeds that for the upstream station (1026 vs. 387). The low number of game fishes reported in Table V-20 is also surprising in that Lake Livingston is generally conceded to be an excellent lake with a large game fish population. The generalization is probably true and the samples from one station do not reflect the overall condition of game fish populations

Table V-19. Results of electrofishing samples July 12, September 13, and December 6, 1972 Trinity River at Highway 21 bridge near Midway, Texas [1]

Common Name[2]	Number	% of Number	Weight (pounds)	% Weight	Average Weight (Pounds)
longnose gar	1	.25	.06	.06	.06
gizzard shad	174	44.96	20.16	22.63	.11
river carpsucker	1	.26	.56	.62	.56
spotted sucker	1	.26	.25	.29	.25
carp	4	1.04	13.19	14.80	3.30
red shiner	50	12.91	.14	.15	<.01
yellow bullhead	1	.26	.06	.07	.06
flathead catfish	2	.52	.07	.08	.04
blackstripe topminnow	3	.78	.01	.01	<.01
brook silverside	2	.51	.01	.01	<.01
white bass	6	1.55	6.25	7.02	1.04
largemouth black bass	18	4.65	18.20	20.42	1.01
warmouth	2	.52	.34	.38	.17
redear sunfish	3	.78	.30	.34	.10
bluegill sunfish	22	5.68	1.89	2.12	.09
longear sunfish	67	17.31	2.56	2.87	.04
black crappie	19	4.91	10.96	12.30	.58
white crappie	11	2.85	14.10	15.83	1.28
TOTAL: (18 species)	387	100.00	89.11	100.00	-
Game Fish	56	14.48	49.58	55.65	-
Other Species	331	85.52	39.53	44.35	-

[1] Data supplied by Texas Parks and Wildlife Department personnel.

[2] Scientific names are included in Appendix V-07.

Table V-20. Results of electrofishing samples July 11, September 12, and December 5, 1972 Trinity River at Highway 19 bridge crossing[1]

Common Name[2]	Number	% of Number	Weight (pounds)	% Weight	Average Weight (Pounds)
gizzard shad	563	54.88	70.38	46.20	.13
threadfin shad	312	30.40	2.18	1.43	.01
river carpsucker	1	.10	1.38	.90	1.38
carp	10	.97	57.52	34.51	5.26
golden shiner	1	.10	.03	.02	.03
red shiner	2	.19	.01	.01	.10
bullhead minnow	1	.10	.02	.01	
channel catfish	3	.29	8.13	5.34	2.71
black bullhead catfish	2	.20	2.19	1.43	1.10
flathead catfish	1	.10	.50	.33	.50
tidewater silverside	1	.10	.01	.01	.01
brook silverside	30	2.93	.11	.07	<.01
white bass	2	.19	2.56	1.68	1.28
yellow bass	3	.29	.59	.39	.20
largemouth black bass	6	.59	2.99	1.96	.50
warmouth	3	.29	.31	.20	.10
redear sunfish	2	.20	.06	.04	.03
bluegill sunfish	54	5.26	4.85	3.19	.09
longear sunfish	27	2.63	1.69	1.11	.06
white crappie	2	.20	1.78	1.17	.89
TOTAL: (20 species)	1026	100.00	152.34	100.00	-
Game Fish	14	1.36	15.96	10.48	-
Other Species	1012	98.64	136.38	89.52	-

[1] Data supplied by Texas Parks and Wildlife Department personnel.

[2] Scientific names are included in Appendix V-07.

within the lake. Two forage fish species, the gizzard shad and the threadfin shad, were very abundant, comprising 86.5% of the total number of fishes collected. The average weights of these two species were low, thus indicating that they were small enough to serve as food items for the game fish populations. Catfishes and sunfishes dominated the game fish populations at this site, which is to be expected in lakes of this geographical region.

Data (Table V-21) from the Loop 12-Trinity River bridge collecting site at the south edge of Dallas indicate that conditions were not favorable for fish populations there at the time of sampling. Mosquitofish and gizzard shad were the only fishes taken and these were not present in abundance. Personal communication with residents and fishermen in the area indicated that game fishes are virtually unknown from this segment of the river. Carp, gars, bullhead catfishes, and other rough fishes are occasionally taken by anglers, sighted in the river, or found after fish kills. Much organic waste is discharged in to the river immediately upstream from this station so the paucity of fish species is not unexpected.

Data (Table V-22) from the Post and Paddock Riding Club area between Fort Worth and Dallas are quite similar to those from the Loop 12-Trinity River bridge station. Species diversity was low with one species, the red shiner comprising 99.66% of the total. Mosquitofish, gizzard shad, and black bullhead catfish were the only other species collected at this station. All four of these species are known to be tolerant of adverse ecological conditions and are among the most pollution-tolerant species of this geographical region. The degree of pollution, as judged by visual observation, at this station did not appear to be as great as at the Loop 12-Trinity River station. In spite of the better overall appearance, no game fishes were taken at this site.

A hiatus in game fish populations in the Trinity River apparently exists from near Fort Worth downstream to the Crockett, Texas area. Game fishes do currently exist west of Fort Worth in the headwaters of the Trinity River drainage system (Mark Kelly, pers. Comm.), but conditions are apparently so bad in the area indicated above that virtually no game fishes are found and few rough fish species. Joe Mayhew, as quoted in the Houston Chronicle October 14, 1972 said "...the upper Trinity River is so polluted it will support only trash fish such as carp and

Table V-21. Results of seine sampling, October 28, 1972 at the Loop 12 and Trinity River bridge

Common Name[1]	Number	% of Number	Total Wt. (grams)	% Weight	Average Wt. (grams)	Average Length (mm)
mosquitofish	11	91.63	4.51	40.60	0.41	27.27
gizzard shad	1	8.37	6.60	59.40	6.60	89.00
TOTAL: (2 species)	12	100.00	11.11	100.00	-	-
Game Fish	0	0	0	0	-	-
Other Species	12	100.00	11.11	100.00	-	-

[1] Scientific names are included in Appendix V-07.

Table V-22. Results of seine sampling, October 28,1972 at the Post and Paddock Riding Club

Common Name[1]	Number	% of Number	Total Wt. (grams)	% Weight	Average Wt. (grams)	Average Length (mm)
mosquitofish	3211	99.66	2215.59	98.68	0.69	32.4
red shiner	7	.22	7.49	984	1.07	44.0
black bullhead catfish	2	.06	14.20	.24	7.10	79.5
gizzard shad	2	.06	8.20	.24	4.10	78.5
TOTAL: (4 species)	3222	100.00	2245.48	100.00	-	-
Game Fish	0	0	0	0	-	-
Other Species	3222	100.00	2245.48	100.00	-	-

[1] Scientific names are included in Appendix V-07.

alligator gars." Mayhew further stated, "...that recent seinings in the river yielded only one sport fish, a catfish, between the Loop 12 bridge in Dallas and the Texas 7 bridge near Crockett. He said the river is devoid of adequate oxygen to support sports fish from Dallas to the South Freestone County line, north of Crockett. Mayhew said gar and carp can live in water with insufficient oxygen for sports fish." Clearly the situation is not presently favorable for the development of game and sport fish populations over a large porion of the mid- and upper segments of the Trinity River.

Collections were made at Lake Livingston Dam in the Trinity River by seine and gill nets on February 2 and 3, 1973, respectively. Relatively still water in this area enabled these investigators to use gill nets one of the few times during this phase of the study. The data from these collections are presented in Tables V-23 and V-24, respectively. The seine sample (Table V-23) did not yield any game fish species. Relatively large numbers of tidewater silversides and threadfin shad, however, were taken. Gill net samples (Table V-24) were more successful in capturing larger fish species. Rough and forage fish species comprised 99.23% of the total individuals collected via gill net. Gizzard shad and river carpsuckers dominated gill net samples with 92.31% of the total being comprised of these two species. Only one game fish, a black crappie, was taken by gill net.

The negative effects of high water in the Trinity River and its tributaries on sampling were vividly illustrated in collections made at Richland Creek (Table V-25) and the Trinity River at the Highway 287 bridge (Table V-26). Only one species was taken at each of these sites, the golden shiner at the Highway 287 bridge and the red shiner at Richland Creek. These sample sites are within the zone discussed by Mayhew which is generally unsuited for the maintenance of game fish populations. No game fish were taken in either of these samples.

Collections made upstream from the Texas State Highway 21 bridge on the Trinity River near Midway, Texas in early March, 1973 (Tables V-27 and V-28) showed somewhat greater diversity than the stations further upstream but still failed to produce significant game fish populations. Red shiners and bullhead minnows, both small, forage fish species, dominated both collections. These ubiquitous species are present in practically all samples taken anywhere in the river system.

Table V-23. Results of seine sampling, February 2,1972 at the Lake Livingston Dam and the Trinity River

Common Name[1]	Number	% of Number	Total Wt. (grams)	% Weight	Average Wt. (grams)	Average Length (mm)
golden shiner	3	1.58	5.70	<.55	1.90	53.00
threadfin shad	43	21.94	78.26	7.55	1.82	45.60
gizzard shad	16	8.12	741.60	71.51	46.35	127.60
bullhead minnow	1	.51	970	<.11	.70	32.00
mosquitofish	15	7.65	2.70	<.25	.18	20.10
tidewater silverside	118	60.20	207.68	20.03	1.76	57.70
TOTAL: (6 species)	196	100.00	1036.64	100.00	-	-
Game Fish	0	0	0	0	-	-
Other Species	196	100.00	1036.64	100.00	-	-

[1] Scientific names are included in Appendix V-07.

Table V-24. Results of gill net sampling, February 3,1973 at Lake Livingston Dam and the Trinity River

Common Name[1]	Number	% of Number	Total Wt. (grams)	% Weight	Average Wt. (grams)	Average Length (mm)
gizzard shad	101	77.96	4529.78	84.52	451.78	258.96
river carpsucker	19	14.62	5674.92	10.51	298.68	220.25
yellow bullhead catfish	1	.77	681.00	1.26	681.00	298.45
black bullhead catfish	1	.77	227.00	<.50	227.00	203.20
black crappie	1	.77	567.50	1.05	567.50	254.00
yellow bass	4	3.08	789.60	1.46	197.40	176.25
golden shiner	1	.77	75.02	<.50	75.02	133.35
bluegill sunfish	1	.77	113.50	<.50	113.50	127.00
lake chubsucker	1	.77	227.00	<.50	227.00	203.20
TOTAL: (9 species)	130	100.00	53985.32	100.00	-	-
Game Fish	1	.77	567.50	1.05	-	-
Other Species	129	99.23	53417.82	98.95	-	-

[1] Scientific names are included in Appendix V-07.

Table V-25. Results of seine sampling, February 24,1973, Richland Creek at Texas State Highway 488 bridge

Common Name[1]	Number	% of Number	Total Wt. (grams)	% Weight	Average Wt. (grams)	Average Length (mm)
red shiner	161	100.00	84.4	100.00	.52	249
TOTAL: (1 species)	161	100.00	84.8	100.00	-	-
Game Fish	0	0	0	0	-	-
Other Species	161	100.00	84.4	100.00	-	-

[1] Scientific names are included in Appendix V-07.

Table V-26. Results of seine sampling, February 24, 1973, Trinity River at Texas State Highway 287 bridge

Common Name[1]	Number	% of Number	Total Wt. (grams)	% Weight	Average Wt. (grams)	Average Length (mm)
golden shiner	1	100.00	.30	100.00	.30	340
TOTAL: (1 species)	1	100.00	.30	100.00	-	-
Game Fish	0	0	0	0	-	-
Other Species	1	100.00	.30	100.00	-	-

[1] Scientific names are included in Appendix V-07.

Table V-27. Results of seine sampling, March 4,1973, approximately 6 miles upstream from Texas State Highway 21 bridge near Midway, Texas

Common Name[1]	Number	% of Number	Total Wt. (grams)	% Weight	Average Wt. (grams)	Average Length (mm)
mosquitofish	1	≤1.0	.30	.30	<1.0	220.00
blackspotted topminnow	1	<1.0	.10	.10	<1.0	210.00
gizzard shad	16	2.7	653.44	40.84	71.7	1300.00
red shiner	356	61.0	174.54	.49	19.1	194.00
mimic shiner	1	<1.0	.10	.10	<1.0	270.00
emerald shiner	1	<1.0	.10	.10	<1.0	240.00
ghost shiner	16	2.7	3.36	.21	<1.0	229.00
bluegill sunfish	5	<1.0	3.60	.72	<1.0	282.00
longear sunfish	5	<1.0	6.70	1.34	<1.0	338.00
bullhead minnow	183	31.0	69.54	.38	7.6	265.00
TOTAL: (10 species)	585	100.00	911.78	-	100.00	-
Game Fish	0	0	0	-	0	-
Other Species	585	100.00	911.78	-	100.00	-

[1] Scientific names are included in Appendix V-07.

Table V-28. Results of seine sampling, March 4,1973, approximately 8 miles upstream from Texas State Highway 21 bridge near Midway, Texas

Common Name[1]	Number	% of Number	Total Wt. (grams)	% Weight	Average Wt. (grams)	Average Length (mm)
red shiner	1338	57.2	307.74	.23	60.8	199.00
bullhead minnow	995	42.5	189.05	.19	37.4	234.00
bluegill sunfish	3	<1.0	1.59	.53	<1.0	253.00
ghost shiner	2	<1.0	.26	.13	<1.0	250.00
white crappie	1	<1.0	7.20	7.20	1.4	680.00
TOTAL: (5 species)	2339	100.00	505.84	-	100.00	-
Game Fish	1	<1.0	7.20	-	1.5	-
Other Species	2338	99.0	498.64	-	98.5	-

[1] Scientific names are included in Appendix V-07.

DISCUSSION

Fish Species Profile Analyses

In the following pages an attempt has been made to synthesize and condense data regarding habitat preference, reproductive habits, food habits, specializations, economic value, and probable response to impoundment and channelization for 18 of the most important fish species in the Trinity River system. Published data are extensive for some of these species, but lacking for others.

Construction of dams is known to result in considerable change in the fish fauna of a river system (Keith, 1964; Fritz, 1968), but few detailed "before-and-after" ecological surveys have been conducted to determine the extent of and the underlying reasons for these changes. It is the intent of this discussion to provide basic data on life histories of several of the most important fish species in the river system.

FISH SPECIES PROFILE #1

Common Name: Largemouth Black Bass

Habitat Preference: This species is widely distributed in rivers and lakes of East Texas and prefers areas of submerged aquatic vegetation, logs, stumps, brush, and underwater rock formations. It is typically found in relatively deep, quiet, soft-bottomed areas. Upper and lower lethal temperatures for this species acclimated at 20°C are 32.5°C and 5.5°C, respectively (Brett, 1956).

Reproduction: This species normally begins spawning in Texas in early spring (February-May) when water temperatures approach 60°F. Circular nests are usually constructed in water 2-8 feet deep on practically any substrate other than soft mud bottoms. In heavily wooded lakes this species has been known to spawn on the top of submerged logs. Females deposit 2000-25,000 eggs in the nest and are then driven away by the male. Fry hatch in 5-10 days, depending upon water temperature, and are then guarded, in a school, by the male for several days. This species may reach sexual maturity and spawn at one year. Life expectancy is estimated to be 6-10 years. Aveaage size is 2-6 pounds.

Food habits:
Young: plankton, small insect larvae, small fish, insects, crayfish, frogs
Adults: larger fish, frogs, crayfish, snakes, etc.

Specializations (Morphological, Physiological, Behavioral, etc.): Protective coloration consisting of bars, blotches, and generally dark color pattern provides concealment; streamlined body for speed in swimming and large mouth for ingestion of large prey; adults may form schools which feed en masse on schools of gizzard and threadfin shad; highly predaceous.

Economic Value: This is the most popular and most sought-after game fish in Texas. This species is also quite edible. More time and money are spent in quest of this fish than any other species of freshwater fish in the state. No commercial fishery exists for this species.

Probable Response to Channelization: This species is adaptable to lake-type sluggish water habitats and probably will not be extremely adversely affected by the

impoundments and canal *if* suitable spawning substrates are made available *or* if sufficient numbers of young can be reared and stocked in the system by Texas Parks and Wildlife Department hatcheries located throughout the state. Like most other game fish species the population size will decline as the canal-impoundment system ages. Therefore, short-term effects will probably be positive, while long-term effects will be negative.

FISH SPECIES PROFILE #2

Common Name: Spotted Bass

Habitat Preference: This species prefers much the same type environment as the largemouth bass, but is generally considered to be a more riverine species. In addition, it seems to prefer clearer lakes and streams than the largemouth black bass. This fish is native to rivers, natural lakes, and streams of East Texas. From previous work (Hall, 1972) this species appears to be far less numerous than the largemouth bass in the Trinity River drainage system.

Reproduction: Little is known regarding the spawning habits of this species other than the fact that it is a nest-builder. Data from McCune (1971) indicate that this species migrates upstream in the spring to spawn in small tributaries of lakes and rivers. Spawning probably occurs at an earlier date than for the closely related largemouth bass. Average size is usually 1-2 pounds with a maximum of about 5-6 pounds.

Food Habits: Young feed on plankton, insect larvae, small fish, and insects, whereas adults feed primarily on larger fish, crayfish, and frogs.

Specializations (Morphological, Physiological, Behavioral, etc.): Same as for largemouth bass in regard to color pattern, speed, and large mouth, but no data are available on schooling habits in this species.

Economic Value: Highly valued as a food and game fish. No commerical fishery exists for this species.

Probable Response to Channelization: The initial impact on this species will probably be negative since it, presumably, prefers flowing, clear water for day-to-day living and spawning. Locks and dams may impede migration and the lentic nature of the canal and its impoundments may not be conducive to adequate spawning in this species. As with the largemouth bass, the long-term effects will probably be negative.

FISH SPECIES PROFILE #3

Common Name: Bluegill

Habitat Preference: This fish prefers shallow, weedy areas, but will thrive in a variety of habitats. It is widely distributed in the U.S. And is native to the Trinity River system. Adults usually show a preference for deep water, while the young frequent shallower areas. Upper and lower lethal temperatures for this fish acclimated at 20°C, are approximately 31.5°C and 5.0°C, respectively (Brett, 1956).

Reproduction: This species spawns over an extended period of time, beginning when water temperatures reach 65°F and continuing on into the fall. It is quite prolific and overpopulation and stunting may result from the high reproductive potential of this species. Nests are typical "sunfish-type" circular nests and are built on sand or gravel shoals. It is a colonial nester with beds of 100 or more in some areas. A mature female may spawn 100,000 eggs per spawning season. This fish may attain a length of 12 inches and a weight of 1 pound, although the average size is much smaller.

Food Habits: Young normally feed on plankton, small insects, and algae, while adults take insects, crayfish, small fish, and various types of aquatic vegetation.

Specializations (Morphological, Physiological, Behavioral, etc.): One of the most advantageous traits of this species is its high reproductive potential. In addition, males may mate with several females over the extended spawning period. Protective coloration of dark vertical bars on the sides of the body provides for concealment in aquatic vegetation. This species also utilizes many types of food items in its diet.

Economic Value: Highly valued as a food and game fish by many anglers. This is a sporty, but small fish with firm, tasty flesh. No commercial value because of its small size.

Probable Response to Channelization: Probably negative since sand and gravel substrates normally used in spawning may be lacking. The demersal ("heavier than water") eggs produced by this species are not suited for development in mud or silt substrates. Also, if shoreline aquatic vegetation is removed from the canal, little or no protection will be available for this species. High

reproductive potential may partially compensate for some of the handicaps above.

FISH SPECIES PROFILE #4

Common Name: Redear Sunfish

Habitat Preference: The redear sunfish generally prefers deep waters of lakes and streams. This fish also apparently prefers areas of lakes and streams with limited amounts of vegetation. This species is common the Trinity River system (Hall, 1972).

Reproduction: This fish generally spawns in early spring in deeper water than the bluegill and probably does not spawn over a prolonged period of time as does the bluegill. It is a colonial nester and congregates in large schools for spawning. The redear does not overpopulate as readily as the bluegill. Redears may attain a length of 12 inches and a weight of 2 pounds.

Food Habits: Young feed on plankton and adults take snails, bottom organisms, and small fishes.

Specializations (Morphological, Physiological, Behavioral, etc.): This is one of the larger "panfishes" so it is probably not as susceptible to predation as many of the smaller sunfishes. Colonial nesting facilitates reproduction.

Economic Value: Highly desirable food and sport fish. Relatively large size and firm, tasty flesh make this fish one of the most sought after species of the "cane pole" crowd. No commerical value.

Probable Response to Channelization: Probably negative because of the spawning habitat requirements and lower reproductive potential than the bluegill.

FISH SPECIES PROFILE #5

Common Name: Black Crappie

Habitat Preference: This fish is predominately limited to the clear acid waters of East Texas and is typically found around submerged logs, brush, stumps, and aquatic vegetation. It is common in the Trinity River drainage system, although it is less numerous than the closely related white crappie.

Reproduction: Black crappie readily overpopulate waters resulting in large numbers of stunted fish. Spawning occurs in March-April in East Texas waters. Nests are typical circular "sunfish-type". A 10-inch female may spawn 14,000 eggs per spawning season. Water temperatures of approximately 58-64°F are required for spawning. Sexual maturity is usually attained at 2-3 years. Black crappie may nest in gravel areas or on bottom materials muddier than those acceptable to other sunfishes (Eddy and Surber, 1947).

Food Habits: Young usually feed on plankton, small fish, and insects while aquatic and land insects, larger fishes, and crustaceans normally are taken by adults (Harlan and Speaker, 1956; Sigler, 1959). This species is highly predaceous and apparently competes more with the largemouth and spotted basses than with other sunfishes.

Specializations (Morphological, Physiological, Behavioral, etc.): Probably a colonial nester (although data are lacking); adaptable in its food habits; normally found in large schools; quite prolific; dark color and blotches on the sides of the body also provide concealment.

Economic Value: Highly valued as a food and game fish. Crappies are the largest of the so-called "panfishes" and are readily taken by the angler during the spring spawning season. No commercial value.

Probable Response to Channelization: This species adapts well to a lake-type environment and probably would not, initially, be extremely adversely affected by channelization *if* suitable spawning substrates were made available. Removal of all shoreline brush and vegetation would be detrimental to this species. The long-term effect is negative, as with most other game and sport species.

FISH SPECIES PROFILE #6

Common Name: White Crappie

Habitat Preference: White crappie tolerate turbid conditions better than black crappie (Neal, 1963). They are also generally more tolerant of warm, sluggish waters than black crappie. White crappie usually predominate in waters with pH values over 7.0 (Toole, 1950). They are fond of cover such as aquatic vegetation, logs, brush, etc. They are found in both flowing and still waters. This species is quite common in the Trinity River system.

Reproduction: This fish usually spawns in East Texas from March-July beginning when water temperatures reach 64-68°F. White crappie often spawn near brush piles, stumps, or rock outcroppings (Toole, 1950), but they seem to prefer to deposit their eggs on plant materials (Hansen, 1951; Whiteside, 1964). Sexual maturity is usually attained in 2-3 years. A 10-inch female may produce 25,000 eggs per spawning season. This species has a tendency to overpopulate and become stunted (Goodson, 1966).

Food Habits: Zooplankton, crustaceans, insects and fishes are commonly eaten by both young and adults (Harland and Speaker, 1956; Sigler, 1959). Growth rates of white crappie are significantly reduced in turbid waters (Hall, et al., 1954).

Specializations (Morphological, Physiological, Behavioral, etc.): This species is very prolific and adapts well to alkaline lake waters. They also form schools and are able to remain active and feed at low temperatures (Goodson, 1966). This species is also able to tolerate high water temperatures in southern latitudes. This fish is also adaptable in its food habits and is highly predaceous.

Economic Value: Highly valued as a food and game fish. Easily caught by anglers during the spring spawning season and at night, during summer, under lanterns and floodlights. No commercial fishery exists for this species.

Probable Response to Channelization: A sustained white crappie yield can be expected only if adequate cover is retained in the canal system. If this requirement is met

and if a large forage fish population (e.g., threadfin shad) is present in the system this species should thrive. High turbidity will favor this species to the exclusion of the black crappie. The long-term effect, as for the other game fish species, appears to be negative.

FISH SPECIES PROFILE #7

Common Name: White Bass

Habitat Preference: This species thrives in rivers and larger lakes of East Texas and is common in the Trinity River system. It prefers open water of lakes over sandy shoal areas and ridges. Young are often found in shallow inshore areas. The white bass was originally found in Texas only in Caddo Lake, but has been widely distributed and is now found statewide (McCune, 1971).

Reproduction: The white bass is very prolific and a mature female may produce up to 1 million eggs at one spawning (Moore, 1963). When flowing tributaries are available this species prefers to migrate upstream to spawn. It does, however, spawn over windswept sand and gravel areas of lakes. Fry hatch in 2-3 days and usually reach a size of 8-9 inches the first year.

Food Habits: Adults feed primarily on forage fishes such as gizzard and threadfin shad. Fry feed on plankton, gradually changing to a diet of insects, crustaceans, and fish as they mature. Life expectancy is usually 3-6 years. Average size usually ranges from 1-1-1/2 pounds with a maximum of approximately 5 pounds.

Specializations (Morphological, Physiological, Behavioral, etc.): This species is well-known for its schooling behavior. Schools often feed en masse on schools of forage fishes. The white bass is not easily reared in hatcheries, but stocking is usually unnecessary because of the high reproductive potential. This is a voracious, fast-swimming, fast-growing species.

Economic Value: This species is highly valued as a game and food fish by the fisherman. The flesh is firm and edible. It is readily taken by the sport fisherman on jigs, spoons, spinner baits, minnows, etc. No commercial value.

Probable Response to Channelization: This species adapts well to lake-type habitats, especially when numerous tributaries are present which allow spawning. If access to such tributaries is allowed in the construction of the canal-impoundment system this species will probably thrive

since it is not highly dependent upon shoreline vegetation or other underwater cover. This is an open-water fish with an extremely high reproductive potential, both of which attributes will be advantageous in adapting to a non-flowing or moderately-flowing canal-impoundment system.

FISH SPECIES PROFILE #8

Common Name: Striped Bass

Habitat Preference: This species is an anadromous saltwater fish native to the Atlantic coast of the U.S. There it normally migrates upriver during the spawning season. Striped bass are now present in the Trinity River system where they have been stocked by the Texas Parks and Wildlife Department. This is an open-water, deep-water species of lakes and large rivers.

Reproduction: Spawning occurs in spring in flowing water of streams. Flowing water is necessary to keep the eggs in motion until they hatch, therefore this species requires a flowing river length of approximately 50 miles for successful reproduction. Water temperature of 60°F or slightly higher is required for spawning. Eggs are broadcast in areas with considerable current (Raney, 1952). Sixty hours after fertilization, at 64°F, the eggs hatch. The young reach a length of 9mm ten days after fertilization (Pearson, 1938).

Food Habits: Young striped bass normally feed on small fish and crustaceans while adults feed primarlly upon clupeid (shad-like) fishes (Goodson, 1964; Stevens, 1958).

Specializations (Morphological, Physiological, Behavioral, etc.): This species adapts well to freshwater environments and is able to feed on large forage fishes (e.g., gizzard shad) thus occupying an otherwise vacant niche in most inland freshwater lakes. It is tolerant of a wide range of temperatures. Like the white bass, it forms schools and members of a school normally feed en masse on schools of forage fishes. This is a large (30-40 pounds), fast-growing, fast-swimming, highly predaceous fish.

Economic Value: The striped bass is a highly valued food and game fish in areas where a sufficiently large population density permits a fishery. This species currently is of limited value in the Trinity River system because of its scarcity. No commercial fishery exists in the Trinity River, at present, for this fish.

<u>Probable Response to Channelization:</u> Debatable. Spawning is probably impossible now, before channelization, and further impoundment and consequent reduction of flowing water will further reduce the possibility of spawning. The only method for developing a striped bass fishery in the Trinity River system is by periodic stocking. A high mortality rate in fingerlings is common, therefore it will be difficult to establish this fish within the system. Since the striped bass is an open-water species it may adapt well to the larger lakes of the system and may survive in the deeper waters.

FISH SPECIES PROFILE #9

Common Name: Channel Catfish

Habitat Preference: The channel catfish prefers flowing water of rivers and streams but also adapts well to lake-type environments. It may migrate upstream in swift water since it tends to seek out channels and reacts positively toward currents (Moore, 1963). This fish is common in the Trinity River system.

Reproduction: Spawning usually occurs from May-July in Texas as the water temperature reaches 75°F (McCune, 1971). Spawning areas are sought under large rocks and ledges, in hollow logs, or in holes swept out in mud banks. Artificial containers have also been used with success in fish hatcheries. The number of eggs spawned by a sexually mature female usually ranges upward from 10,000. The male cares for the eggs after spawning.

Food Habits: Omnivorous. The channel catfish feeds on practically any type of organic matter, dead or alive. Common food items taken include fish, freshwater mussels, algae, pondweeds, snails, insects, crayfish, mice, cotton rats, toads, frogs, etc.

Specializations (morphological, Physiological, Behavioral, etc.): The diverse diet is advantageous to this species. The body is streamlined and, thus, well-adapted to fast-flowing waters. Care of the eggs by the male insures a high hatch rate. This species is also quite tolerant of high temperatures and low oxygen levels.

Economic Value: This is one of the most important food and game fishes of the Trinity River system. It is taken year-round by sport and commerical fishermen.

Probable Response To Channelization: As with the other game fish populations there should be a positive effect initially, but a gradual decline in numbers as the impoundments age. Reduction in the number of possible spawning sites in the canal proper may be partially alleviated by the increased number of sites in the larger reservoirs of the system. Migratory habits of this fish will probably assure dispersal throughout the system. The fish is common in the system now and no stocking will be necessary to establish it in the impoundments.

FISH SPECIES PROFILE #10

Common Name: Blue Catfish

Habitat Preference: This species seems to prefer deeper waters of rivers and lakes, coming into the shallower back-waters in the spring (Moore, 1963). It is relatively common in the lower Trinity River, but is rarer upstream. This fish is native to the larger rivers of Texas and has been stocked in many Texas lakes (McCune, 1971).

Reproduction: Little is known regarding the spawning habits of the blue catfish, but it is supposedly similar to the channel catfish in regard to nest site selection, care of eggs by male, etc. This species spawns in Texas in May and June.

Food Habits: The blue catfish feeds primarily on fish, crustaceans, insects, aquatic insect larvae, fresh water mussels, and other living or dead materials. This fish may reach a size of 100 pounds or more.

Specializations (morphological, Physiological, Behavioral, etc.): Same as for channel catfish.

Economic Value: This is a highly valued food and game fish, but is less abundant than the closely-related channel catfish. This fish is taken by sport and commercial fishermen in the Trinity River basin.

Probable Response To Channelization: The effects on this fish are debatable due to the lack of data regarding spawning habits, etc., but presumably it will follow the pattern outlined previously for the channel catfish.

FISH SPECIES PROFILE #11

Common Name: Flathead Catfish

Habitat Preference: this large catfish is commonly found in the large rivers and lakes of Texas and is very common in the Trinity River system. Flatheads generally prefer sluggish, deep waters which have an abundance of logs, undercut banks, brush, etc.

Reproduction: the spawning period of this species, in Texas, usually begins in late May and may extend through August. Males select hollow logs, underwater caves, or rock crevices as nesting sites. The female then deposits her eggs and the male actively defends them until the fry hatch (usually 4-6 days, depending upon water temperature). The fry disperse almost immediately after hatching (McCune, 1971).

Food Habits: fingerlings feed on insect larvae for approximately the first year with a gradual transition to a fish diet. Adults feed almost exclusively on small fish. Adults reach 100 pounds or more and may live 15-20 years or longer.

Specializations (morphological, Physiological, Behavioral, etc.): care of the eggs by the male reduces predation and insures a high hatch rate. The mottled color pattern, particularly in the young, also provides concealment from predators. This species adapts well to large lakes.

Economic Value: this is a highly valued food fish because of its large size, excellent table qualities, and ease of capture (via trotline, hoop net, gill net, rod and reel, etc.). This is one of the most important commercial fishes of the Trinity River system.

Probable Response To Channelization: possibly few adverse effects will accrue to this species since it is adaptable insofar as diet and type of aquatic habitat are concerned. Possible adverse effects may result, however, if suitable nesting sites are not available in the canal-impoundment system. Complete clearing of all timber, removal of shoreline vegetation, and elimination of undercut banks may significantly reduce possible spawning sites for this

species. Some progress has been made in rearing this species in fish hatcheries, therefore an adequate population could, perhaps, be maintained by a stocking program if necessary.

FISH SPECIES PROFILE #12

Common Name: Common Carp

Habitat Preference: This species is found throughout the Trinity River system. It may be found in the mainstream, tributaries, lakes, and oxbows. It was introduced in Texas in the late 1800's (McCune, 1971). This is primarily a warm-water, pollution-tolerant fish. Some preference is shown for sluggish water over fast-flowing streams.

Reproduction: This fish is very prolific. Small (3-5 pound) females may spawn up to 700,000 eggs per spawning season (Moore, 1963). Eggs are strewn about in shallow weedy water. The eggs stick to aquatic vegetation and no care is provided for eggs or young.

Food Habits: The fry feed on plankton while adults are omnivorous. Organic detritus and small bottom organisms are commonly taken as well as small fish and other small, free-swimming aquatic organisms. Growth is usually quite rapid with weights of 50 pounds or more attainable. This species may live up to 47 years in captivity (McCune, 1971).

Specializations (morphological, Physiological, Behavioral, etc.): Omnivorous food habits, high reproductive potential, and the ability to live in practically any kind of aquatic habitat (including even brackish water along the Texas coast) make this one of the hardiest and most widespread fishes in the Trinity River system.

Economic Value: This species is generally held in low esteem, but sport and commercial fishermen do frequently take this species. The numerous sharp intermuscular bones and "muddy taste" usually deter the would-be consumer, but it is eaten by some. This fish is large; easily taken in gill, hoop, and trammel nets; and is marketed by commercial fishermen along the lower Trinity River.

Probable Response To Channelization: This species will probably thrive in a canal-impoundment system, since it is highly adaptable to nearly all aquatic habitats.

FISH SPECIES PROFILE #13

Common Name: Smallmouth Buffalo

Habitat Preference: This species normally prefers deeper waters of rivers and lakes, but generally shows a preference for flowing water (Moore, 1963). This fish is common in the mainstream and oxbow lakes of the lower Trinity River.

Reproduction: Spawning occurs in the spring at water temperatures of 60-65°F. The eggs are randomly strewn in shallow water over aquatic vegetation or mud bottoms. The eggs hatch in 7-14 days. No parental care is provided during or after the incubation period. Large numbers of eggs are produced by mature females.

Food Habits: The diet includes algae, seeds of aquatic plants, small mollusks, insect larvae, and numerous species of bottom organisms. Maximum size for this fish is approximately 15-20 pounds.

Specializations (morphological, Physiological, Behavioral, etc.): The diverse diet is beneficial o this species as is the high reproductive potential.

Economic Value: his is one of the most important commercial fishes of the lower Trinity River. It is occasionally taken by anglers, but more often is taken by commercial fishermen using gill, hoop, and trammel nets. This fish has numerous intermuscular bones, but the flesh is firm and tasty.

Probable Response To Channelization: the overall impact upon this species will probably be negative since it seems to prefer deep, flowing water rather than sluggish, shallow waters. It apparently does not adapt well to large impoundments. This species is currently neither propagated nor stocked by the Texas Parks and Wildlife Department, therefore natural stocks may not be able to establish and maintain large populations in the canal-impoundment system.

FISH SPECIES PROFILE #14

Common Name: Freshwater Drum

Habitat Preference: Ubiquitous. This fish adapts well to impoundments and is found in all major rivers of Texas, including the Trinity. This fish is usually found in medium to shallow depth water with soft bottoms (Hinckley, 1963).

Reproduction: No nest is constructed by this species. The pelagic (free-floating) eggs are broadcast over gravel or clay bottoms. Drum usually spawn in large schools during May and June. No care is provided for eggs or fry.

Food Habits: The fry normally feed on plankton while adults feed upon aquatic insects, crustaceans, snails, clams, small fish, etc. (Moore, 1963). This fish may attain a weight of 40 pounds or more.

Specializations (morphological, Physiological, Behavioral, etc.): This fish is highly adaptable to diverse aquatic environments. The diverse diet and high reproductive potential are also advantageous traits.

Economic Value: Firm, white flesh with few bones makes the demand for this fish quite high. This is one of the top commercial species taken from the Trinity River and is marketed under the names of "gou", "gasper-gou", "rockfish", etc. This fish is also taken by sport fishermen on live baits, such as minnows and worms. The large size and ease of capture make the freshwater drum one of the highly sought commercial fishes of the river.

Probable Response To Channelization: Probably positive. This fish adapts well to impounded water and is found from the headwaters of the Trinity to the Gulf. The diverse diet, tolerance of turbid water, and high reproductive potential are factors which should favor this species in a canal system.

FISH SPECIES PROFILE #15,16

Common Name: Longnose Gar & Alligator Gar

Habitat Preference: Gars, in general, prefer warm lakes and slow-moving streams. During the summer they frequent the surface waters and lie motionless for minutes at a time (Suttkus, 1963). In streams below barriers (such as Lake Livingston Dam) large numbers of longnose gar can be seen basking or surfacing for air on warm sunny days. Alligator gars may winter in deep holes of the lower Trinity River or Trinity Bay (Lloyd Brannen, pers. Comm.). Both species are very common in the Trinity River.

Reproduction: Spawning takes place in fresh water from April to mid-July. Gar move into the shallows to spawn with each female accompanied by 1-4 males. Eggs are strewn about and fertilization is external. Both eggs and milt are poisonous. The eggs are adhesive and adhere to the substratum. No care is provided for the eggs or young.

Food Habits: Gar feed primarily on other fishes, most of which are forage fishes such as gizzard shad. In the lower Trinity River blue crabs and striped mullet are common food items. Garbage has also been reported as part of the diet by Suttkus (1963). Alligator gars weighing over 300 pounds have been reported and longnose gars over 100 pounds are commonly taken from the lower Trinity River.

Specializations (morphological, Physiological, Behavioral, etc.): Gars are ancient fishes which show a multitude of advantageous traits such as thick, ganoid scales which completely cover the body; an air-breathing, highly vascularized swimbladder; numerous large, sharp teeth; high reproductive potential; poisonous sex products; diverse diet; etc.

Economic Value: Both longnose and alligator gars are commonly taken and marketed by commercial fishermen along the lower Trinity River. These are very important commercial fishes and many are processed into fish sticks, fish cakes, etc., by various seafood processors (Hall, 1972).

<u>Probable Response To Channelization:</u> The longnose gar thrives in a shallow lake-type environment, therefore its response should be positive. The alligator gar, however, does not appear to be quite as adaptable to large impoundments and thus may not fare quite as well as the longnose and spotted gars. Both the longnose and alligator gar, however, should establish large populations within the confines of the canal-impoundment system.

FISH SPECIES PROFILE #17,18

Common Name: Gizzard Shad & Threadfin Shad

Habitat Preference: Both these species are commonly found in flowing, as well as sluggish waters and both abound in the Trinity River system. Both appear to favor open, deep, clear water; and abrupt shoreline, little or no shoreline vegetation, and waters which contain large plankton populations (Miller, 1960).

Reproduction: Spawning season for both species is from April-July at temperatures ranging from 50-70°F (Jester and Jensen, 1972). Various substrates such as sandy, gravel-covered bars; silt beds; etc, are utilized. Water depths used for spawning range from 6 inches to 50 feet. Eggs are adhesive and some sink to the bottom while others float. Spawning normally occurs in large schools with much rolling and tumbling in evidence. No parental care is provided for eggs or fry. Mature females may spawn up to 70,000 eggs per season.

Food Habits: Numerous food items are taken by these filter-feeding fishes, such as algae, cladocerans, plant debris, water mites, aquatic insect larvae, small mollusks, small fish, etc., (Jester and Jensen, 1972). Gizzard shad may attain a length of 18 inches while threadfin shad seldom exceed 12 inches.

Specializations (morphological, Physiological, Behavioral, Etc.): The tremendous reproductive potential and diverse diet are the major factors which assure the success of these two species. Schooling may also be advantageous.

Economic Value: These small, bony fishes are not usually eaten by humans, but they do serve as a basic link in the aquatic food chain. Both are excellent forage fishes and serve in the diets of most, if not all, game fishes (and some rough fishes) in the Trinity River system. No commercial fishery or sport fishery exists for these two species.

Probable Response To Channelization: Probably positive. Fluctuating water levels favor gizzard shad production and and increase in total dissolved solids favors both species

(Jenkins, 1970). Both species should flourish in a canal-impoundment system. The richness (high organic content) of the waters of this system should assure good growth conditions for both species.

Reservoir Fisheries Management Problems

The difficulties in assessing the effects of ecological parameters on fish populations in reservoirs have been well-stated by Jenkins (1964,1968,1970). Various workers have, in the past, used many data in an attempt to correlate fish production with various parameters. In an attempt to utilize and analyze only the most significant data regarding reservoirs and fish production, Jenkins (1970) used fish standing crop data from 140 reservoirs, which at that time comprised 25% of the total surface area in the U.S. The data were derived from population sampling studies conducted by fishery agencies in 17 states, including 520 annual summaries based on over 2,000 individual sample areas.

The various parameters used by Jenkins are listed, with the results of his Logarithmic Partial Correlation analysis, in Table V-29. For a definition of terms used in the table the reader is referred to the original publication. Fishes which do not occur in the Trinity River system have been deleted from Jenkins' data.

Jenkins has summarized some of the important environmental conditions in regard to sports fishes as follows:

> "some generalizations on sport fish production influents (0.20 confidence interval) include: with increase in reservoir area a decrease in bullheads, sunfishes and black basses; with increase in mean depth, an increase in sunfishes and decrease in channel catfish, largemouth bass and white crappie; with increase in outlet depth, an increase in combined sport fish crop; with increased water level fluctuation, an increase in flathead catfish, black bass and white crappie and a decrease in sunfish crops; with increase in storage ratio (i.e., lower water exchange rate), increase in bullhead, channel catfish, largemouth bass, and white crappie crops and decreases in flathead catfish, bluegill and longear sunfish; with increased shore development, increase in channel catfish, white bass and bluegill and increase in redear sunfish and black crappie; with increase in TDS (total dissolved solids), increase in catfishes, white bass, green sunfish, largemouth bass and white crappie

and a decrease in bluegill, warmouth and black crappie crops."

With respect to forage fishes Jenkins (1970) stated that "Forage fish (gizzard and threadfin shad) crops are positively influenced by increase in TDS. Gizzard shad production also responds positively to increased outlet depth, but negatively to water level fluctuation. Threadfin shad is positively influenced by growing season length and negatively by storage ratio."

From Jenkins (1968) Multiple Regression Analyses some general relationships were apparent between standing crop and environmental conditions. These were: (1) with an increase in total dissolved solids there was an increase in standing crop and sport fish yield; (2) with increased age of the reservoir there was an increase in gizzard and threadfin shad crops and commercial harvest of rough fishes, but a decrease in sport harvest and little effect on total standing crop; (3) with increased storage ratio (i.e., lower water exchange rate) there was a decrease in sport harvest; (4) with an increase in reservoir area there was a decrease in sport harvest; (5) with an increase in mean depth, there were decreases in total standing crop, and sport and commercial harvest; and (6) with increased shore development there were increases in total standing crop and sport harvest, but a decrease in the commercial harvest.

Admittedly, the data are still incomplete on Trinity River fish populations, but with more precise data on fish standing crop, production rates, and limnological factors fishery biologists should be better able to advise regarding the design and operation of lakes and canals in the system to increase sport and commercial fishery yields in the future.

Distribution of Fishes in the Trinity River System

Any attempt to categorize Trinty River fishes as living in a specific type of aquatic environment is likely to be an exercise in futility because: (1) the ichthyofauna of the river is apparently changing rapidly (e.g., certain species, such as the paddlefish and pallid shiner have, apparently, disappeared from the river within recent years); (2) the river is subject to periodic flooding which causes dispersal of many species into "atypical" habitats; (3) river modification via Lake Livingston Dam stops the

Table V-29. Logarithmic partial correlation of nine environmental variables with the standing crop (pounds per acre) of various species and species groups in reservoirs at the 0.20 confidence level, 0.05 level=*, and 0.01 level=**. Number of reservoirs is listed in parentheses (slightly modified from Jenkins, 1970)

Environmental Variables	Effect Of Standing Crop Positive	Negative
Surface Area (in acres)	pickerel** (40)	bullhead catfishes (87) sunfishes (136) black basses (135)
Mean Depth (in feet)	spotted sucker (48) bluegill (129) longear sunfish** (69) redear sunfish (68) sunfishes	longnose gar** (44) carp (100) buffalofishes** (47) channel catfish (109) largemouth bass (134) white crappie* (102) all sport fishes (139) freshwater drum (57)
Outlet Depth (in feet)	gizzard shad (116) carp carpsuckers (55) buffalofishes* bullhead catfishes catfishes** (124) green sunfish** (74)	spotted sucker**

	largemouth bass white crappie all sport fishes**	
Water Level Fluctuation (mean annual, in feet)	spotted gar (31) flathead catfish (76) black basses white crappie*	gizzard shad* pickerel* carpsuckers redear sunfish* sunfishes
Storage Ratio (mean annual)	bullhead catfishes* channel catfish** redear sunfish largemouth bass white crappie all sport fishes	threadfin shad (61) spotted sucker* flathead catfish* bluegill longear sunfish
Shore Development (at mean pool level)	buffalofishes** carp channel catfish* white bass (73) bluegill all sport fishes*	redear sunfish black crappie (98)
Total Dissolved Solids (in ppm)	longnose gar gizzard shad** threadfin shad carp** carpsuckers** catfishes** white bass**	spotted gar pickerel spotted sucker buffalofishes bluegill warmouth (99) black crappie*

	green sunfish**	
	largemouth bass*	
	white crappie	
Growing Season (frost-free, in days)	threadfin shad**	pickerel*
	channel catfish*	spotted sucker$
	white bass	buffalofishes
	bluegill*	
	redear sunfish**	
	black basses**	
	black crappie$	
Age of Reservoir (in years)	buffalo fishes	pickerel
	channel catfish**	carp
	white bass	cullhead catfishes**
	freshwater drum**	flatheat catfish
		bluegill**
		sunfishes*
		spotted bass* (59)

movement of migratory fishes, such as the American eel, upstream; (4) a rather long segment of the mid-river is unfit for most of the fish species because of pollution; and (5) many fishes are able to live in a variety of aquatic habitats with no clear preference for any given type.

In view of the foregoing statements, an attempt has been made (Table V-30) to summarize the usual habitat preferences and distribution of most of the extant Trinity River fish species. Data bearing upon this aspect of the study have been taken from Minckley (1963), Rainwater (1972), Conner (pers. Comm.), Kelly (pers, comm.), Hall (1972), and Rozenburg, *et al.* (1972). Questionable species and recently introduced non-native game fishes have not been included in Table V-30.

The listing of a species under a specific heading in the following table is not meant to imply that it is found only in that habitat, but that it is commonly associated with that type habitat. Conversely, some species are limited to very specific habitats.

SUMMARY

The Trinity River supports, at present, a fish fauna probably comprised of at least 130 species representing approximately 33 inventory to date has documented the occurrence of more than 92 fish species. Families and perhaps as many as 73 genera. No other published river system many of the 130 species are brackish water and marine fishes, but they are, nevertheless, a part of the Trinity River's rich ichthyofauna.

The number of fish species increases downstream in the Trinity River with 56 species reported from the headwaters and approximately 100-125 species for the mid- and lower reaches of the river. Game fishes are virtually unknown in a major portion of the upper river and numerous species are apparently threatened, or have already been extirpated, by man's influence on the Trinity River. Among these are the paddlefish, pallid shiner, scaly sand darter, Sabine shiner, and various other species. Headwater populations of several species of game fishes indicate that they, at one time, did occupy the now depauperate region of the river.

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Table V-30. Habitat distribution of fishes in the Trinity River system.

Small streams with moderate current and hard bottom or sand bottom

- stoneroller (headwaters region of Trinity)
- creek chub
- blackspot shiner
- ribbon shiner
- redfin shiner
- blacktail shiner
- pallid shiner (headwaters region of Trinity)
- sand shiner (headwaters region of Trinity)
- Sabine shiner
- spotted sucker
- blacktail redhorse
- plains killifish
- redbreast sunfish
- spotted bass
- freckled madtom
- dusky darter
- goldstripe darter
- scaly sand darter
- orangethroat darter (headwaters region of Trinity)

River channel with current of moderate to strong velocity

western silvery minnow
speckled chub
chub shiner
emerald shiner
ghost shiner
mimic shiner
silverband shiner
river carpsucker
blue sucker
black buffalo
alligator gar
longnose gar
blue catfish
flathead catfish
freshwater drum
tidewater silverside
Mississippi silverside

Table V-30 (cont.)

Sluggish-water species (oxbow lakes, sloughs, etc.) - Usually with aquatic vegetation and soft-bottom; generally clear, shallow, acid waters

weed shiner
western creek chubsucker
western lake chubsucker
grass pickerel
blackstripe topminnow
blackspotted topminnow
starhead topminnow
golden topminnow
bowfin
pirate perch
bantam sunfish
flier
spotted sunfish
dollar sunfish
banded pygmy sunfish
cypress darter
bluntnose darter
slough darter

Ubiquitous species

gizzard shad
threadfin shad
spotted gar
carp
bullhead minnow
fathead minnow
golden shiner
pugnose minnow
red shiner
smallmouth buffalo
green sunfish
orange-spotted sunfish
bluegill
longear sunfish
warmouth
redear sunfish
largemouth bass
white crappie
black crappie
white bass
yellow bass
channel catfish
black bullhead catfish
yellow bullhead catfish
tadpole madtom
freshwater drum
logperch
brook silverside
western mosquitofish

Table V-30 (cont.)

Marine invaders found primarily in lower Trinity River - coastal plain zone

Gulf menhaden
finescale menhaden
bay anchovy
sailfin molly
striped mullet
white mullet
mountain mullet
golden croaker
sand seatrout
spotted seatrout
spot
black drum
red drum
bull shark
Atlantic needlefish
Gulf killifish
bayou killifish
sheepshead minnow
rainwater killifish
diamond killifish
saltmarsh killifish
rough silverside
Gulf pipefish
American eel

pinfish
sheepshead
southern flounder
skipjack herring,
fat sleeper
darter goby
freshwater goby
naked goby
bay whiff
lined sole
hogchoker
blackcheek tonguefish

No endemic, rare, or endangered fish species are now recognized in the system. Most of the fishes inhabiting this system, including those above, are widespread geographically and many are quite tolerant of adverse environmental conditions.

Future re-colonization of the upper Trinity River down to Lake Livingston by now-missing riverine fish species is a possibility if: (1) basic water quality of the upper river is greatly improved (and maintained at a high level); (2) breeding populations of these fish species still exist in Lake Livingston or tributaries of the river; (3) food chain organisms of the riverine species have not been extirpated from the system by severe, prolonged pollution; (4) no future adverse changes occur in the structural configuration of the river channel proper and its tributaries; (5) a sufficient, sustained water flow is maintained year-round.

No specific fisheries recommendations can be made at this time because of the multiplicity of factors involved, but this investigator feels that it is reasonable to assume that many of the now-missing riverine species will return when the conditions and criteria listed above are corrected and/or attained.

Numerous ecological factors are operant on the fishes now occupying the Trinity River. Dams, reservoirs, locks, and canals will modify river habitats and thereby cause changes in species composition, distribution, and abundance. Some species will benefit from such changes, while others will be eliminated (particularly those species which are highly adapted to stream-type, flowing-water habitats). Some species, however, are ubiquitous and will adapt well to a lacustrine habitat.

A possible alternative approach to the proposed barge canal-flood control system is a single-purpose flood control project which, this investigator feels, will result in many of the same fisheries problems as outlined in this and a previous report (Hall, 1972). Such a flood-control system presumably would involve: (1) construction of dams (both on the river channel proper and its tributaries); (2) dredging and deepening the Trinity River channel; (3) straightening the river channel by cutting across incipient oxbows, i.e., large "horseshoe bends" in the river; (4) removal of shoreline vegetation, logs, and debris (in conjunction with number 2 above).

As mentioned above, some fish species will thrive in almost any type aquatic habitat, but on the whole most native food and game fishes will not adapt well to a highly modified river channel as would result from the changes described above. To be sure, there are certain benefits in a flood-control system which may include: (1) water conservation, (2) flood prevention, (3) longer stretches of flowing water in the river channel (than with a barge canal-lock and dam system), (4) upstream lakes which may act as settling basins for silt and other headwater pollutants, (5) greater recreational potential, and (6) greater fisheries potential than with a barge canal system.

Data provided herein, based on limited sampling during this phase of the project indicate that game fishes are not abundant upstream from Lake Livingston in the river. Data from a previous study (Hall, 1972) however, showed that a sport (and commercial) fishery of significant magnitude exists downstream from Lake Livingston Dam in the river.

Data have been provided herein regarding habitat preference, reproductive habits, specializations, economic importance, and the possible impact of channelization on many of the important food, game, forage, and rough fishes of the Trinity River system. Additional data have also been provided on environmental variables which relate specifically to and influence reserovir populations of fishes occurring in the river system.

In summation, this study was made to provide, as completely as possible, a record of the species composition, distribution, and abundance of the fishes of the Trinity River system. Hopefully, this survey will provide a basis for further studies on the effects of environmental changes on the Trinity River fish fauna.

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APPENDIX V

Appendix V-01. Species and numbers of small mammals caught in snap traps along a 1,500 meter transect on different dates at Study Areas 1-10

Species	Study Area 1 Date (1972-1973)					Total	Habitat[1]		
	Sept 23	Dec 3	Jan 15	Mar 17	May 12		Wd	Th	Gr
cotton rat *Sigmodon hispidus*	0	1	0	0	0	1	1	0	0
Total Individuals Caught	0	1	0	0	0	1	1	0	0
Total Traps Set	100	100	100	100	50	450	200	105	145
Percent Success	0.0	1.0	0.0	0.0	0.0	0.2	0.5	0.0	0.0

[1] Wd: hardwood forests and woodlands; Th: thickets, scrub, and forest edge; Gr: grasslands, croplands, pastures, and weedy fields.

Appendix V-01 (cont.)

Species	Study Area 2 Date (1972-1973)					Total		Habitat [1]		
	Feb 24	Mar 18	Apr 7					Wd	Th	Gr
cotton mouse *Peromyscus gossypinus*	0	1	0			1		1	---	---
Total Individuals Caught	0	1	0			1		1	---	---
Total Traps Set	100	100	100			300		300	0	0
Percent Success	0.0	1.0	0.0			0.3		0.3	---	---

[1]Wd: hardwood forests and woodlands; Th: thickets, scrub, and forest edge; Gr: grasslands, croplands, pastures, and weedy fields.

Appendix V-01 (cont.)

Species	Study Area 3 Date (1972-1973) Oct 13	Dec 2	Jan 28	Mar 3	May 12	Total	Habitat[1] Wd	Th	Gr
hispid pocket mouse *Perognathus hispidus*	0	0	0	1	0	1	0	1	---
fulvous harvest mouse *Reithrodontomys fulvescens*	0	1	3	0	0	4	0	4	---
white-footed mouse *Peromyscus leucopus*	0	1	0	0	0	1	1	0	---
cotton mouse *Peromyscus gossypinus*	0	0	3	2	1	6	6	0	---
Total Individuals Caught	0	2	6	3	1	12	7	5	---
Total Traps Set	60	100	100	100	33	393	263	130	0
Percent Success	0.0	2.0	6.0	3.0	3.0	3.1	2.7	3.8	---

[1] Wd: hardwood forests and woodlands; Th: thickets, scrub, and forest edge; Gr: grasslands, croplands, pastures, and weedy fields.

Appendix V-01 (cont.)

Species	Study Area 4 Date (1972-1973)					Total	Habitat[1]		
	Oct 8	Nov 11	Apr 8				Wd	Th	Gr
deer mouse <u>Peromyscus maniculatus</u>	0	1	0			1	0	1	---
cotton mouse <u>Peromyscus gossypinus</u>	13	3	3			19	17	2	---
eastern woodrat <u>Neotoma floridana</u>	0	0	1			1	1	0	---
Total Individuals Caught	13	4	4			21	18	3	---
Total Traps Set	100	100	100			300	270	30	0
Percent Success	13.0	4.0	4.0			7.0	6.7	10.0	---

[1] Wd: hardwood forests and woodlands; Th: thickets, scrub, and forest edge; Gr: grasslands, croplands, pastures, and weedy fields.

Appendix V-01 (cont.)

Species	Study Area 5 Date (1972-1973) Oct 22	Jan 14	Feb 25	Mar 25	Apr 19	Total	Habitat[1] Wd	Th	Gr
cotton mouse *Peromyscus gossypinus*	0	0	0	1	0	1	0	1	0
Total Individuals Caught	0	0	0	1	0	1	0	1	0
Total Traps Set	100	100	100	100	100	500	100	225	175
Percent Success	0.0	0.0	0.0	1.0	0.0	0.2	0.0	0.4	0.0

[1] hardwood forests and woodlands; Th: thickets, scrub, and forest edge; Gr: grasslands, croplands, pastures, and weedy fields.

Appendix V-01 (cont.)

Species	Study Area 6 Date (1972-1973) Nov 12	Jan 27	Mar 4	Mar 30		Total	Habitat[1] Wd	Th	Gr
least shrew *Cryptotis parva*	1	0	0	0		1	0	0	1
fulvous harvest mouse *Reithrodontomys fulvescens*	0	7	11	0		18	1	11	6
deer mouse *Peromyscus maniculatus*	1	1	1	0		3	1	1	1
cotton mouse *Peromyscus gossypinus*	1	2	15	5		23	6	8	9
cotton rat *Sigmodon hispidus*	2	0	1	0		3	0	0	3
Total Individuals Caught	5	10	28	5		48	8	20	20
Total Traps Set	100	100	100	100		400	60	160	180
Percent Success	5.0	10.0	28.0	5.0		12.0	13.3	12.5	11.1

[1] Wd: hardwood forests and woodlands; Th: thickets, scrub, and forest edge; Gr: grasslands, croplands, pastures, and weedy fields.

Appendix V-01 (cont.)

Species	Study Area 7 Date (1972-1973)					Total	Habitat[1]		
	Nov 4	Nov 17	Jan 20	Mar 24	Apr 20		Wd	Th	Gr
fulvous harvest mouse *Reithrodontomys fulvescens*	2	0	0	1	0	3	1	2	---
deer mouse *Peromyscus maniculatus*	1	0	0	0	0	1	1	0	---
cotton mouse *Peromyscus gossypinus*	0	4	1	3	0	8	8	0	---
cotton rat *Sigmodon hispidus*	1	0	0	0	0	1	0	1	---
Total Individuals Caught	4	4	1	4	0	13	10	3	---
Total Traps Set	100	100	100	100	100	500	375	125	0
Percent Success	4.0	4.0	1.0	4.0	0.0	2.6	2.7	2.4	---

[1] Wd: hardwood forests and woodlands; Th: thickets, scrub, and forest edge; Gr: grasslands, croplands, pastures, and weedy fields.

Appendix V-01 (cont.)

Species	Study Area 8 Date (1972-1973) Oct 21	Dec 9	Apr 1	Apr 29		Total	Habitat[1] Wd	Th	Gr
short-tailed shrew *Blarina brevicauda*	1	0	0	0		1	1	0	0
fulvous harvest mouse *Reithrodontomys fulvescens*	0	1	0	0		1	0	1	0
cotton mouse *Peromyscus gossypinus*	0	0	0	1		1	1	0	0
Total Individuals Caught	1	1	0	1		3	2	1	0
Total Traps Set	100	100	80	100		380	210	110	60
Percent Success	1.0	1.0	0.0	1.0		0.8	1.0	0.9	0.0

[1] Wd: hardwood forests and woodlands; Th: thickets, scrub, and forest edge; Gr: grasslands, croplands, pastures, and weedy fields.

Appendix V-01 (cont.)

Species	Study Area 9 Date (1972-1973)					Total	Habitat[1]		
	Sept 16	Oct 28	Feb 10	Mar 10	Apr 28		Wd	Th	Gr
cotton mouse *Peromyscus gossypinus*	0	0	0	5	2	7	7	---	---
Total Individuals Caught	0	0	0	5	2	7	7	---	---
Total Traps Set	65	100	100	100	100	465	465	0	0
Percent Success	0.0	0.0	0.0	5.0	2.0	1.5	1.5	---	---

[1] Wd: hardwood forests and woodlands; Th: thickets, scrub, and forest edge; Gr: grasslands, croplands, pastures, and weedy fields.

Appendix V-01 (cont.)

Species	Study Area 10 Date (1972-1973)					Total		Habitat[1]		
	Dec 10	Feb 11	Mar 11	May 13				Wd	Th	Gr
fulvous harvest mouse *Reithrodontomys fulvescens*	0	0	3	0		3		0	3	0
cotton mouse *Peromyscus gossypinus*	2	0	1	0		3		3	0	0
pygmy mouse *Baiomys taylori*	0	0	1	0		1		0	0	1
Total Individuals Caught	2	0	5	0		7		3	3	1
Total Traps Set	100	100	100	50		350		180	75	95
Percent Success	2.0	0.0	5.0	0.0		2.0		1.7	4.0	1.1

[1] Wd: hardwood forests and woodlands; Th: thickets, scrub, and forest edge; Gr: grasslands, croplands, pastures, and weedy fields.

Appendix V-02. Large mammals and mammal signs along a 1,500 meter transect on censuses at Studv Areas 1-10

Study Area 1*	Maximum and Total Numbers									
	Individuals Seen or Heard		Tracks		Feces		Nests		Other[1]	
Species	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.
opossum *Didelphis marsupialis*	1	2			2	2				
armadillo *Dasypus novemcinctus*	2	3	5	13			7	16	14	34
swamp rabbit *Sylvilagus aquaticus*	7	10			4	13				
cottontail rabbit *Sylvilagus floridanus*	1	2			4	6				
fox squirrel *Sciurus niger*	2	6								
fox and/or gray squirrel							6	11		
southern flying squirrel *Glaucomys volans*							3	8		
beaver *Castor canadensis*			1	2					1	2
nutria *Myocastor coypus*			1	1						
coyote *Canis latrans*	1	1			1	3				
coyote and/or dog			7	15						
gray fox *Urocyon cinereoargenteus*	1	2	2	2	1	1				

[1] Diggings, gnawings, or food remains.

* Censused on December 3, January 15, March 17, and May 12 1972-1973.

Appendix V-02 (cont.)

Study Area 1 (Cont.) Species	Maximum and Total Numbers									
	Individuals Seen or Heard		Tracks		Feces		Nests		Other[1]	
	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.
raccoon <u>Procyon lotor</u>			7	19						
striped skunk <u>Mephitis mephitis</u>	2	3								
Total		29		60		25		35		28
Average Number Per Census	7.2		15.0		6.2		8.8		7.0	

[1] Diggings, gnawings, or food remains.

Appendix V-02 (cont.)

Study Area 2* Species	Maximum and Total Numbers									
	Individuals Seen or Heard		Tracks		Feces		Nests		Other[1]	
	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.
opossum *Didelphis marsupialis*			2	3						
armadillo *Dasypus novemcinctus*	1	1	3	5			1	2	5	8
swamp rabbit *Sylvilagus aquaticus*	2	3	5	13	18	37				
fox squirrel *Sciurus niger*	2	3								
fox and/or gray squirrel			5	12			5	11	11	29
beaver *Castor canadensis*			4	5	1	1			2	4
nutria *Myocastor coypus*									2	3
coyote *Canis latrans*					3	4				
coyote and/or dog			5	13						
gray fox *Urocyon cinereoargenteus*			1	2						
raccoon *Procyon lotor*			7	10	1	1				
Total		7		63		43		13		44
Average Number Per Census	2.3		21.0		14.3		4.3		14.7	

[1] Diggings, gnawings, or food remains.

* Censused on February 24, March 18, and April 7, 1973.

Study Area 3* Species	Maximum and Total Numbers									
	Individuals Seen or Heard		Tracks		Feces		Nests		Other[1]	
	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.
opossum *Didelphis marsupialis*			3	6	3	3				
armadillo *Dasypus novemcinctus*	4	7	7	19			4	11	13	37
swamp rabbit *Sylvilagus aquaticus*	1	3	5	7	7	24				
cottontail rabbit *Sylvilagus floridanus*	2	2	2	3	2	9				
fox squirrel *Sciurus niger*	5	8								
fox and/or gray squirrel							11	30	8	12
beaver *Castor canadensis*			4	8			3	7	10	25
eastern woodrat *Neotoma floridana*							2	3		
coyote *Canis latrans*	6	11			3	8				
coyote and/or dog			14	35						
gray fox *Urocyon cinereoargenteus*			2	2						
raccoon *Procyon lotor*			9	22	1	1				

[1] Diggings, gnawings, or food remains.

* Censused on October 13, December 2, January 28, March 3, and May 12, 1972-1973.

Appendix V-02 (*cont.*)

Study Area 3 (Cont.) Species	Maximum and Total Numbers									
	Individuals Seen or Heard		Tracks		Feces		Nests		Other[1]	
	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.
striped skunk *Mephitis mephitis*	1	2	7	12						
bobcat *Lynx rufus*			1	2						
white-tailed deer *Odocoileus virginianus*			2	4						
Total		33		120		45		51		74
Average Number Per Census	6.6		24.0		9.0		10.2		14.8	

[1] Diggings, gnawings, or food remains.

Appendix V-02 (cont.)

Study Area 4* Species	Individuals Seen or Heard		Tracks		Feces		Nests		Other[1]	
	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.
opossum *Didelphis marsupialis*			2	3						
armadillo *Dasypus novemcinctus*			7	17					10	31
swamp rabbit *Sylvilagus aquaticus*	4	7			8	25				
cottontail rabbit *Sylvilagus floridanus*	2	3								
fox squirrel *Sciurus niger*	6	10								
fox and/or gray squirrel							6	15		
beaver *Castor canadensis*			1	1					7	15
eastern woodrat *Neotoma floridana*							1	3		
coyote *Canis latrans*	3	4			1	2				
coyote and/or dog			4	10						
gray fox *Urocyon cinereoargenteus*			1	1						
raccoon *Procyon lotor*			12	29	1	1				

[1] Diggings, ganwings, or food remains.

* Censused on October 8, November 11, April 8, and May 13, 1972-1973.

Appendix V-02 (cont.)

Study Area 4 (Cont.)	Maximum and Total Numbers									
	Individuals Seen or Heard		Tracks		Feces		Nests		Other[1]	
Species	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.
striped skunk *Mephitis mephitis*			1	2						
mink *Mustela vison*			1	1						
bobcat *Lynx rufus*			1	1						
white-tailed deer *Odocoileus virginianus*	8	19	11	33	3	9				
Total		43		98		37		18		46
Average Number Per Census	10.8		24.5		9.2		4.5		11.5	

[1] Diggings, gnawings, or food remains.

Appendix V-02 (cont.)

Study Area 5* Species	Maximum and Total Numbers: Individuals Seen or Heard		Tracks		Feces		Nests		Other[1]	
	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.
eastern mole *Scalopus aquaticus*			1	1						
armadillo *Dasypus novemcinctus*	6	8	3	6			6	13	7	17
swamp rabbit *Sylvilagus aquaticus*	1	1			3	6				
cottontail rabbit *Sylvilagus floridanus*	4	5			2	2				
fox and/or gray squirrel							7	15		
plains pocket gopher *Geomys bursarius*							12	31		
coyote *Canis latrans*	1	1				1	3			
coyote and/or dog			6	17						
raccoon *Procyon lotor*			4	9	1	1				
striped skunk *Mephitis mephitis*			1	1						
white-tailed deer *Odocoileus virginianus*	8	12	21	53						
Total		27		87		12		59		17
Average Number Per Census	6.8		21.8		3.0		14.8		4.2	

[1] Diggings, gnawings, or food remains

* Censused on January 14, February 25, March 25, and April 19, 1973.

Appendix V-02 (cont.)

Study Area 6*	Maximum and Total Numbers									
	Individuals Seen or Heard		Tracks		Feces		Nests		Other[1]	
Species	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.
opossum *Didelphis marsupialis*			1	1						
armadillo *Dasypus novemcinctus*	1	1	3	5			3	7	5	10
swamp rabbit *Sylvilagus aquaticus*	2	4			7	18				
cottontail rabbit *Sylvilagus floridanus*	2	3			2	5				
fox and/or gray squirrel							6	13	2	2
southern flying squirrel *Glaucomys volans*									3	4
coyote *Canis latrans*					2	2				
coyote and/or dog			9	19						
raccoon *Procyon lotor*			6	14						
striped skunk *Mephitis mephitis*	2	2	2	2						
white-tailed deer *Odocoileus virginianus*			8	22	4	7				
Total		10		63		32		20		16
Average Number Per Census	2.5		15.8		8.0		5.0		4.0	

[1] Diggings, gnawings, or food remains.

* Censused on November 12, January 27, March 4, and March 30, 1972-1973.

Appendix V-02 (cont.)

Study Area 7* Species	Maximum and Total Numbers									
	Individuals Seen or Heard		Tracks		Feces		Nests		Other[1]	
	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.
opossum *Didelphis marsupialis*	2	2	2	2	1	1				
armadillo *Dasypus novemcinctus*	7	8	3	7			7	19	13	30
swamp rabbit *Sylvilagus aquaticus*	4	9	1	2	27	62				
cottontail rabbit *Sylvilagus floridanus*					4	6				
fox and/or gray squirrel	2	3	1	1			8	25	3	3
beaver *Castor canadensis*									1	1
coyote *Canis latrans*	3	3								
coyote and/or dog			9	15						
gray fox *Urocyon cinereoargenteus*			1	2						
raccoon *Procyon lotor*			11	22						
striped skunk *Mephitis mephitis*			2	3						
white-tailed deer *Odocoileus virginianus*			12	21						
Total		25		75		69		44		34
Average Number Per Census	6.2		18.8		17.2		11.0		8.5	

[1] Diggings, gnawings, or food remains.

* Censused on November 4, November 17, January 20, and March 24, 1972-1973.

Appendix V-02 (cont.)

Study Area 8*

Species	Maximum and Total Numbers									
	Individuals Seen or Heard		Tracks		Feces		Nests		Other[1]	
	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.
opossum *Didelphis marsupialis*			1	1						
armadillo *Dasypus novemcinctus*	4	6					2	4	7	17
swamp rabbit *Sylvilagus aquaticus*	2	4			6	12				
cottontail rabbit *Sylvilagus floridanus*	1	2			1	2				
fox squirrel *Sciurus niger*	2	2								
fox and/or gray squirrel	1	1					5	12		
nutria *Myocastor coypus*	3	3	4	4						
coyote *Canis latrans*	1	1			1	1				
coyote and/or dog			8	22						
raccoon *Procyon lotor*			8	17						
white-tailed deer *Odocoileus virginianus*	1	2	2	3						
Total		21		47		15		16		17
Average Number Per Census	5.2		11.8		3.8		4.0		4.2	

[1] Diggings, gnawings, or food remains.

* Censused on October 21, December 9, April 1, and April 29, 1972-1973.

Appendix V-02 (cont.)

Study Area 9* — Species	Maximum and Total Numbers — Individuals Seen or Heard Max.	Tot.	Tracks Max.	Tot.	Feces Max.	Tot.	Nests Max.	Tot.	Other[1] Max.	Tot.
opossum *Didelphis marsupialis*			2	2						
armadillo *Dasypus novemcinctus*			1	1	2	2	2	2	2	3
swamp rabbit *Sylvilagus aquaticus*	5	7			4	13				
gray squirrel *Sciurus carolinensis*	1	1								
fox and/or gray squirrel	3	3	1	1			3	8		
beaver *Castor canadensis*									1	1
eastern woodrat *Neotoma floridana*					1	1	2	4		
coyote *Canis latrans*					1	1				
coyote and/or dog			6	7						
gray fox *Urocyon cinereoargenteus*			1	1						
raccoon *Procyon lotor*			5	16						
striped skunk *Mephitis mephitis*			1	2						

[1] Diggings, gnawings, or food remains (note: wild pigs abundant)

* Censused on October 28, February 10, March 10, and April 28, 1972-1973.

Appendix V-02 (cont.)

Study Area 9 (Cont.) Species	Maximum and Total Numbers									
	Individuals Seen or Heard		Tracks		Feces		Nests		Other[1]	
	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.
white-tailed deer _Odocoileus virginianus_			4	6						
Total		11		36		17		14		4
Average Number Per Census	2.8		9.0		4.2		3.5		1.0	

[1] Diggings, gnawings, or food remains.

Appendix V-02 (cont.)

Study Area 10*	Maximum and Total Numbers									
Species	Individuals Seen or Heard		Tracks		Feces		Nests		Other[1]	
	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.
opossum *Didelphis marsupialis*	1	1								
armadillo *Dasypus novemcinctus*	1	2	2	3			2	3	6	12
swamp rabbit *Sylvilagus aquaticus*	1	1	2	2	2	6				
cottontail rabbit *Sylvilagus floridanus*					2	2				
gray squirrel *Sciurus carolinensis*	1	1								
fox squirrel *Sciurus niger*	2	2								
fox and/or gray squirrel							8	17		
eastern woodrat *Neotoma floridana*							1	1		
coyote and/or dog			6	9						
gray fox *Urocyon cinereoargenteus*			1	1						
raccoon *Procyon lotor*			3	6	1	1				
striped skunk *Mephitis mephitis*			2	3						

[1] Diggings, ganwings, or food remains.

* Censused on December 10, February 11, March 11, and May 13, 1972-1973.

Appendix V-02 (cont.)

Study Area 10 (Cont.)	Maximum and Total Numbers									
	Individuals Seen or Heard		Tracks		Feces		Nests		Other[1]	
Species	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.	Max.	Tot.
white-tailed deer *Odocoileus virginianus*			3	4						
Total		7		28		9		21		13
Average Number Per Census	1.8		7.0		2.2		5.2		3.2	

[1] Diggings, gnawings, or food remains (note: wild pigs abundant).

Appendix V-03. Species and numbers of birds recorded on censuses at Study Areas 1-10. An "x" indicates the species was seen on or near the transect at some time other than the census period.

Study Area 1 Species	Census Dates						
	9/23	10/1	12/3	1/15	3/24	4/22	5/12
green heron		x					
little blue heron	1						
cattle egret		1				2	
snowy egret	1						
yellow-cr night heron						1	
wood duck	2					2	
turkey vulture			1				1
red-tailed hawk		1	1		1	2	
Swainson's hawk						x	1
rough-legged hawk			1				
marsh hawk					1		
American kestrel		1				x	
bobwhite	20	1				x	3
killdeer		3	1	3	2		
upland sandpiper						5	
spotted sandpiper							1
solitary sandpiper						1	
Franklin's gull						14	14
mourning dove	2	3	6	4	4	14	6
great horned owl		x					
barred owl					2	2	

Appendix V-03.(cont.)

Study Area 1 (Cont.) Species	Census Dates						
	9/23	10/1	12/3	1/15	3/24	4/22	5/12
chuck-will's widow						x	
chimney swift	7	32				9	7
ruby-throated hummingbird						1	
black-chinned hummingbird							2
belted kingfisher		x				1	
common flicker		18	8				
red-bellied woodpecker	2	7	3	2	1	1	
red-headed woodpecker		1					
yellow-bellied sapsucker		1	1				
hairy woodpecker	2					1	
downy woodpecker	1	1	3	1			4
ladder-backed woodpecker				1			
eastern kingbird						1	1
scissor-tailed flycatcher						1	1
great crested flycatcher						3	2
eastern phoebe	1				1		
least flycatcher	2						1
eastern wood pewee						1	
tree swallow		15					
bank swallow							1
rough-winged swallow						2	

Appendix V-03. (cont.)

Study Area 1 (Cont.) Species	Census Dates						
	9/23	10/1	12/3	1/15	3/24	4/22	5/12
barn swallow		38					9
cliff swallow		1					14
blue jay	28	37	10	8	7	6	1
common crow	11	23	21	9	16	31	4
Carolina chickadee	14	27	15	7	9	15	14
tufted titmouse	2	5	3	5	10	18	12
brown creeper			1	1			
house wren		2			1		
Bewick's wren		5	5	2	1	2	
Carolina wren	8	4	3	6	9	5	3
mockingbird		7	5	3	x	1	
gray catbird		x					
brown thrasher		7		4	2	4	
robin				218	12		
hermit thrush			1	3	3		
Swainson's thrush						3	1
eastern bluebird			6	14			
blue-gray gnatcatcher						4	2
golden-crowned kinglet			4				
ruby-crowned kinglet		2	13	2	5	11	
cedar waxwing			55	18		84	35

Appendix V-03. (cont.)

Study Area 1 (Cont.) Species	Census Dates						
	9/23	10/1	12/3	1/15	3/24	4/22	5/12
redwinged blackbird		36				3	
orchard oriole						1	
great-tailed grackle	10	18			1	15	8
common grackle				1	40	24	
brown-headed cowbird	12	51		14	35	65	13
cardinal	19	60	73	58	43	47	26
indigo bunting						8	9
painted bunting						3	19
dickcissel						21	
purple finch			16				
pine siskin			4				
American goldfinch			6	2			
rufous-sided towhee			8	7	5		
grasshopper sparrow						x	
vesper sparrow					x		
slate-colored junco			27	16	10		
chipping sparrow							4
clay-colored sparrow						x	
field sparrow		31	2	17			
Harris' sparrow			44	x		10	
white-throated sparrow			48	12	29	31	

Appendix V-03.(cont.)

Study Area 1 (Cont.) Species	Census Dates						
	9/23	10/1	12/3	1/15	3/24	4/22	5/12
loggerhead shrike	4	3		2			
starling	15	18	5	84	10	2	
white-eyed vireo						1	2
solitary vireo	3				x		
red-eyed vireo						4	1
black & white warbler							1
prothonotary warbler	2						
Tennessee warbler						2	2
orange-crowned warbler	4	1				1	
Nashville warbler	25					35	
northern parula warbler					1		
yellow warbler	8						
myrtle warbler			1	3	4	2	
black-throated green warbler						2	
chestnut-sided warbler							1
common yellowthroat	3	1				2	
yellow-breasted chat						6	
Wilson's warbler	10						
American redstart	3						
house sparrow	3	30			15	12	
eastern meadowlark		4			x	1	

Appendix V-03. (cont.)

Study Area 1 (Cont.) Species	Census Dates						
	9/23	10/1	12/3	1/15	3/24	4/22	5/12
fox sparrow			15	18			
Lincoln's sparrow			8	9	3	10	
song sparrow			26	32	1		
Total Individuals	225	465	479	569	300	557	226
Total Census Species	30	35	36	33	31	56	25

Total Species all Censuses: 101 (plus 7 non-census species=108)
Total Individuals all Censuses: 2,821 (avg. 403 per census)

Appendix V-03. (cont.)

Study Area 2 Species	Census Dates						
	2/20	2/24	3/25	4/7	4/27		
pied-billed grebe	x		x	x	x		
double-crested cormorant		x	x	x	x		
great blue heron	2	4	4				
little blue heron				6			
cattle egret					9		
yellow-cr night heron					1		
Canada goose		x					
mallard	x		x				
gadwall	x	x	4				
pintail	x	x					
green-winged teal	x	x					
blue-winged teal		x	21	x	x		
northern shoveler		x		x			
wood duck		6	4	5	3		
ring-necked duck	x	x					
canvasback		x					
lesser scaup		x					
ruddy duck		x					
turkey vulture			1				
red-tailed hawk	1	1	1				
Swainson's hawk					1		

Appendix V-03. (cont.)

Study Area 2 (Cont.) Species	Census Dates						
	2/20	2/24	3/25	4/7	4/27		
marsh hawk	x						
osprey					x		
American kestrel	x		x				
bobwhite					x		
American coot	x	x	x	x	x		
killdeer	x	1			x		
ring-billed gull			1				
Franklin's gull			x	x	1		
mourning dove	x				4		
barred owl			1				
chimney swift			15		17		
ruby-throated hummingbird					1		
common flicker	2	4	1	1			
red-bellied woodpecker	11	14	12	6	8		
red-headed woodpecker					x		
pileated woodpecker	x						
hairy woodpecker		1			1		
yellow-bellied sapsucker	1	1					
downy woodpecker	13	9	3	2	4		
western kingbird					x		
scissor-tailed flycatcher				x	x		

Appendix V-03 (cont.)

Study Area 2 (Cont.) Species	Census Dates						
	2/20	2/24	3/25	4/7	4/27		
great crested flycatcher					6		
eastern phoebe	1			x			
least flycatcher					1		
horned lark	. 2						
rough-winged swallow			1		2		
barn swallow			x		x		
cliff swallow					x		
purple martin			x				
blue jay	27	11	4	2	14		
common crow	30	14	17	8	19		
Carolina chickadee	13	15	17	7	10		
tufted titmouse	24	8	16	11	13		
brown creeper	1	1	1				
Bewick's wren	x	x					
Carolina wren	25	20	16	9	11		
mockingbird	x	1	x		x		
brown thrasher	1	3	1		3		
robin	36	74	12	3			
hermit thrush	1	x					
Swainson's thrush					1		
eastern bluebird	3		x				

Appendix V-03. (cont.)

Study Area 2 (Cont.) Species	Census Dates						
	2/20	2/24	3/25	4/7	4/27		
blue-gray gnatcatcher			6	2			
ruby-crowned kinglet	1	3	2	4	8		
cedar waxwing			2	32			
loggerhead shrike			x				
starling	21	68	2		12		
white-eyed vireo				1	2		
solitary vireo					1		
warbling vireo					2		
black & white warbler					1		
Tennessee warbler					5		
Nashville warbler					19		
yellow warbler					2		
myrtle warbler	24	19	10	15	3		
northern waterthrush					1		
common yellowthroat				x	2		
house sparrow	x	x	x	x	x		
eastern meadowlark	x	x	x	x	x		
western meadowlark	x	x	x				
redwinged blackbird	115	210	7	18	11		
Baltimore oriole					1		
rusty blackbird	4	9					

Appendix V-03 (cont.)

Study Area 2 (Cont.) Species	Census Dates						
	2/20	2/24	3/25	4/7	4/27		
great-tailed grackle		33	x		2		
common grackle		4	2	155	13		
brown-headed cowbird		14	2	9	10		
cardinal	33	89	30	52	37		
indigo bunting					1		
dickcissel					x		
purple finch	8	19	1				
American goldfinch	1	7	1				
rufous-sided towhee	4	8	1	2			
lark sparrow					x		
slate-colored junco	10	27	3				
chipping sparrow			x				
field sparrow			x				
Harris' sparrow	x	x			x		
white-crowned sparrow					x		
white-throated sparrow	48	153	41	38	14		
fox sparrow	1	1					
Lincoln's sparrow		2	2	11	6		
swamp sparrow			1				
song sparrow	2	7	1	x			
Total Individuals	466	861	267	399	283		
Total Census Species	31	35	38	23	42		

tal Species All Censuses: 70 (plus 34 non-census species= 104)
tal Individuals All Censuses: 2,276 (avg. 455 per census)

Appendix V-03. (cont.)

Study Area 3 Species	Census Dates						
	9/30	12/2	1/28	3/3	5/12		
white pelican	33						
double-crested cormorant	x						
great blue heron	x						
little blue heron					10		
cattle egret	x				3		
snowy egret					x		
wood stork	140						
mallard				2	x		
blue-winged teal					x		
turkey vulture	7	7	23	4	5		
sharp-shinned hawk	x	1					
Cooper's hawk	x			x			
red-tailed hawk	2		1				
red-shouldered hawk	1	1		4	2		
broad-winged hawk	21						
Swainson's hawk	2				1		
marsh hawk	x		x	x			
peregrine falcon	x						
American kestrel	3		x	x			
bobwhite	x		14		2		
semipalmated plover					x		

Appendix V-03. (cont.)

Study Area 3 (Cont.) Species	Census Dates						
	9/30	12/2	1/28	3/3	5/12		
piping plover					x		
killdeer	2	1		x	2		
golden plover	x						
American woodcock		1	1				
whimbrel					x		
upland sandpiper	x				x		
spotted sandpiper					x		
solitary sandpiper	1						
greater yellowlegs					x		
lesser yellowlegs					x		
willet					x		
pectoral sandpiper					x		
white-rumped sandpiper					x		
Baird's sandpiper					x		
least sandpiper					x		
semipalmated sandpiper					x		
dunlin					x		
long-billed dowitcher					x		
stilt sandpiper					x		
buff-breasted sandpiper	x				x		
Hudsonian godwit					x		

Appendix V-03. (cont.)

Study Area 3 (Cont.) Species	Census Dates						
	9/30	12/2	1/28	3/3	5/12		
Wilson's phalarope					x		
Franklin's gull	4				x		
black tern					x		
mourning dove	5	2	1		1		
yellow-billed cuckoo					4		
great horned owl	1	1					
barred owl	2	1		x	4		
common nighthawk					2		
chimney swift	15				10		
ruby-throated hummingbird					2		
common flicker	22	17	3	1			
pileated woodpecker	1	2	1		2		
red-bellied woodpecker	6	12	9	7	4		
yellow-bellied sapsucker		3	3	3			
hairy woodpecker	1			1	2		
downy woodpecker	5	7	6	10	5		
eastern kingbird					2		
western kingbird					x		
scissor-tailed flycatcher	24				4		
great crested flycatcher					3		
eastern phoebe	2	1					

Appendix V-03. (cont.)

Study Area 3 (Cont.) Species	Census Dates						
	9/30	12/2	1/28	3/3	5/12		
acadian flycatcher					2		
least flycatcher					1		
eastern wood pewee					1		
olive-sided flycatcher	1				2		
horned lark					x		
tree swallow	25						
rough-winged swallow	2						
barn swallow	120				15		
cliff swallow	3				2		
blue jay	85	11	2	8	1		
common crow	20	10	15	7	11		
Carolina chickadee	18	39	16	17	18		
tufted titmouse	7	10	5	9	17		
brown creeper		1	1				
house wren	1						
Bewick's wren			1				
Carolina wren	4	8	5	6	3		
mockingbird	2		3	2	1		
gray catbird					3		
brown thrasher	2	5	2	2			
robin		155	181	25			

Appendix V-03. (cont.)

Study Area 3 (Cont.) Species	Census Dates						
	9/30	12/2	1/28	3/3	5/12		
hermit thrush		6	3	3			
Swainson's thrush					6		
eastern bluebird		2					
blue-gray gnatcatcher					4		
golden-crowned kinglet		6	3	6			
ruby-crowned kinglet	2	7	4	11			
water pipit			x		x		
Sprague's pipit			x				
cedar waxwing		152			x		
loggerhead shrike	8	4	2				
starling			7	3	x		
white-eyed vireo					5		
red-eyed vireo					9		
Philadelphia vireo					1		
warbling vireo					2		
black & white warbler	1				3		
Tennessee warbler					2		
orange-crowned warbler	1	1					
Nashville warbler	3						
northern parula warbler	1						
magnolia warbler					1		

Appendix V-03. (cont.)

Study Area 3 (Cont.) Species	Census Dates						
	9/30	12/2	1/28	3/3	5/12		
myrtle warbler		15	13	3			
bay-breasted warbler					2		
ovenbird					1		
Kentucky warbler					4		
common yellowthroat	1				1		
yellow-breasted chat					1		
American redstart					1		
house sparrow	x	x	x	x	x		
bobolink					x		
eastern meadowlark	3		x	2	4		
yellow-headed blackbird					x		
redwinged blackbird	15	40	x	7	2		
orchard oriole					3		
Baltimore oriole					1		
rusty blackbird				11			
common grackle	28	45		2	10		
brown-headed cowbird	75			11	5		
summer tanager					4		
cardinal	25	77	63	76	68		
indigo bunting	5				25		
painted bunting					8		

Appendix V-03.(cont.)

Study Area 3 (Cont.) Species	Census Dates						
	9/30	12/2	1/28	3/3	5/12		
dickcissel					75		
purple finch		1					
American goldfinch					1		
rufous-sided towhee		2		2			
savannah sparrow			x	x	x		
grasshopper sparrow					x		
vesper sparrow				x			
lark sparrow				x			
slate-colored junco		13	11	1			
Harris' sparrow			x	2			
white-throated sparrow		32	19	28			
fox sparrow		21	20	5			
Lincoln's sparrow	4			1			
song sparrow		6	4				
Total Individuals	759	726	442	282	396		
Total Census Species	49	39	31	33	60		

Total Species All Censuses: 101 (plus 39 non-census species= 140).
Total Individuals All Censuses: 2,605 (avg. 521 per census).

Appendix V-03. (cont.)

Study Area 4 Species	Census Dates						
	10/8	11/11	2/4	4/8	5/13		
great blue heron					1		
green heron					x		
little blue heron				2	28		
cattle egret	2				30		
great egret					x		
snowy egret					x		
American bittern					1		
Canada goose	x						
mallard		8	1				
blue-winged teal				x	x		
wood duck	3	4			2		
hooded merganser			1				
turkey vulture	2	7	7	9	2		
black vulture			x	6			
sharp-shinned hawk		1	2				
red-tailed hawk		x	2	1			
red-shouldered hawk	1			1	1		
Swainson's hawk				1			
bald eagle		2					
American kestrel	x	1					
killdeer	2	7	x	x	2		

Appendix V-03. (cont.)

Study Area 4 (Cont.) Species	Census Dates						
	10/8	11/11	2/4	4/8	5/13		
solitary sandpiper				x	x		
white-rumped sandpiper					x		
least sandpiper					x		
semipalmated sandpiper					x		
ring-billed gull		1					
Franklin's gull		20					
mourning dove	1	7	5		x		
yellow-billed cuckoo					2		
roadrunner		x	x				
screech owl		1					
great horned owl		2					
barred owl	1	1	1	1	4		
chuck-will's-widow					x		
common nighthawk					x		
chimney swift	1						
ruby-throated hummingbird					1		
belted kingfisher				1			
common flicker	8	28	8				
pileated woodpecker	2	4	2	1	2		
red-bellied woodpecker	1	13	9	8	6		
red-headed woodpecker	x		x	1	2		

Appendix V-03. (cont.)

Study Area 4 (Cont.) Species	Census Dates						
	10/8	11/11	2/4	4/8	5/13		
yellow bellied sapsucker	1	9	4				
hairy woodpecker		4					
downy woodpecker	6	12	4	3	5		
eastern kingbird					2		
scissor-tailed flycatcher	x				1		
great crested flycatcher					5		
eastern pheobe	3	1					
acadian flycatcher					2		
least flycatcher					1		
eastern wood pewee					4		
barn swallow	1			1			
blue jay	3	4	1	6	1		
common crow	6	36	24	7	15		
Carolina chicadee	27	43	43	26	28		
tufted titmouse	7	17	19	16	34		
white-breasted nuthatch	5	6	3	2	6		
brown creeper		7	2				
winter wren		5					
Bewick's wren		1					
Carolina wren	3	8	3	5	1		
mockingbird		4	1	1	x		

Appendix V-03. (cont.)

Study Area 4 (Cont.) Species	Census Dates						
	10/8	11/11	2/4	4/8	5/13		
brown thrasher	3	4	1	4	1		
robin			68				
hermit thrush		8	2	1			
Swainson's thrush							
eastern bluebird	1	18	3	3	x		
blue-gray gnatcatcher				8	3		
golden-crowned kinglet		14	3				
ruby-crowned kinglet	3	22	5	4			
water pipit			x				
cedar waxwing		3		28			
loggerhead shrike	2	1	2	1	x		
starling		575	90				
white-eyed vireo				3	2		
yellow-throated vireo				1	2		
solitary vireo			1				
red-eyed vireo					5		
warbling vireo					1		
Tennessee warbler					3		
Nashville warbler				1			
yellow warbler					2		
magnolia warbler					1		
myrtle warbler		4		6			

Appendix V-03. (cont.)

Study Area 4 (Cont.) Species	Census Dates						
	10/8	11/11	2/4	4/8	5/13		
blackburnian warbler					3		
yellow-throated warbler				1	3		
ovenbird					1		
house sparrow			x				
eastern meadowlark			x	3	x		
redwinged blackbird		72	1750				
common grackle	22	108	15		3		
brown-headed cowbird	1	22	6	2	3		
summer tanager				1	7		
cardinal	51	103	72	51	55		
indigo bunting					3		
painted bunting					13		
purple finch		29	85				
pine siskin			8				
American goldfinch		36	195				
rufous-sided towhee		1	3				
savannah sparrow				6			
vesper sparrow		x					
lark sparrow					2		
slate-colored junco		10	28				
field sparrow		3	x				

Appendix V-03. (cont.)

Study Area 4 (Cont.) Species	Census Dates						
	10/8	11/11	2/4	4/8	5/13		
Harris' sparrow		2	12				
white-crowned sparrow			1				
white-throated sparrow		162	254	78			
fox sparrow		10	10				
Lincoln's sparrow		1		5			
song sparrow		1	1				
Total Individuals	169	1473	2757	306	303		
Total Census Species	28	53	43	39	47		

Total Species All Censuses: 97 (plus 15 non-census species= 112).
Total Individuals All Censuses: 5,008 (avg. 1,002 per census).

Appendix V-03. (cont.)

Study Area 5 (Cont.) Species	Census Dates						
	10/22	1/14	2/3	2/25	3/25	4/21	
red-bellied woodpecker		1	1	1	1	3	
yellow-bellied sapsucker			1				
hairy woodpecker			1				
downy woodpecker		4	7	3	2		
eastern kingbird						2	
scissor-tailed flycatcher	4					4	
great crested flycatcher						1	
eastern phoebe	1						
eastern wood pewee						2	
horned lark			3			3	
barn swallow						3	
blue jay	6	5	5	7	1		
common crow	24	15	16	10	3	10	
Carolina chickadee	9	7	9	11	8	9	
tufted titmouse	4	4	2	3	7	15	
brown creeper		1					
house wren	1						
Bewick's wren		2	2	1			
Carolina wren	8	5	9	6	3	8	
mockingbird	7	8	4	5	5	16	
brown thrasher	5	1	1	1		1	

Appendix V-03. (cont.)

Study Area 5 (Cont.) Species	Census Dates						
	10/22	1/14	2/3	2/25	3/25	4/21	
robin		41	23	19			
hermit thrush		2	6	1			
Swainson's thrush						1	
eastern bluebird		5	2		3		
golden-crowned kinglet		1					
ruby-crowned kinglet	6	2	1			2	
Sprague's pipit			1				
cedar waxwing					25	14	
loggerhead shrike	2	2	1	2	1	1	
starling	x	140	x	x	x	x	
black & white warbler						1	
orange-crowned warbler						1	
Nashville warbler						9	
myrtle warbler		8	8	8	4	4	
house sparrow	x	x	x	x	x	x	
eastern meadowlark	32	3	80	34	33	31	
redwinged blackbird		1000	20		1	10	
orchard oriole						4	
common grackle		6	1		4	4	
brown-headed cowbird		20	1	44	11	5	
cardinal	48	41	37	42	24	34	

Appendix V-03. (cont.)

Study Area 5 (Cont.) Species	Census Dates						
	10/22	1/14	2/3	2/25	3/25	4/21	
indigo bunting						1	
dickcissel						2	
purple finch		6	16	17			
pine siskin		x					
American goldfinch		1	11	1			
rufous-sided towhee		1	4	2			
savannah sparrow	13	19	11	22	2	21	
grasshopper sparrow			1		2		
LeConte's sparrow			3				
vester sparrow		71	15	38			
lark sparrow		1				21	
slate-colored junco		18	10	80	4		
clay-colored sparrow						1	
field sparrow		12	12	9	5	1	
Harris' sparrow		36		8			
white-crowned sparrow						1	
white-throated sparrow	5	49	30	45	22	10	
fox sparrow		1	1	1			
Lincoln's sparrow	1			2		1	
song sparrow		11	5	6			
Smith's longspur		140	x				

Appendix V-03. (cont.)

Study Area 5 (Cont.) Species	Census Dates						
	10/22	1/14	2/3	2/25	3/25	4/21	
Total Individuals	229	1769	383	453	214	340	
Total Census Species	24	43	44	34	28	48	

Total Species All Censuses: 81 (plus 3 non-census species= 84).
Total Individuals All Censuses: 3,388 (avg. 565 per census).

Appendix V-03. (cont.)

Study Area 6 Species	Census Dates						
	11/12	1/27	2/18	3/4	3/31	5/27	
great blue heron			1			2	
green heron						1	
little blue heron						9	
cattle egret						81	
great egret					1	1	
wood duck	x						
hooded merganser			2				
turkey vulture	14		1	4	7	1	
sharp-shinned hawk	x						
red-tailed hawk	4	4	3	5	2	1	
red-shouldered hawk	1			1		1	
marsh hawk	1	2	1	1	1		
American kestrel	1	1	1	1			
bobwhite	x	18					
killdeer	3	2	2	2		1	
common snipe	1						
greater yellowlegs	2						
mourning dove	7		1	1		2	
yellow-billed cuckoo						5	
barn owl					1		
barred owl	1	2					

Appendix V-03. (cont.)

Study Area 6 (Cont.) Species	Census Data						
	11/12	1/27	2/18	3/4	3/31	5/27	
ruby-throated hummingbird						2	
common flicker	17	7	8	2			
red-bellied woodpecker	9	3	4	1	1	1	
red-headed woodpecker						1	
yellow-bellied sapsucker	2	1	1	1			
downy woodpecker	3	2	2	3	1	7	
great crested flycatcher						1	
scissor-tailed flycatcher						2	
eastern phoebe	3			1			
willow flycatcher						3	
eastern wood pewee						x	
barn swallow						2	
purple martin						3	
blue jay	20	5	7	5	4	3	
common crow	72	9	12	10	7	10	
Carolina chickadee	14	15	11	15	6	16	
tufted titmouse	5	7	4	3	4	10	
brown creeper	2						
house wren		1					
winter wren	2						
Bewick's wren	1	1		1			

Appendix V-03. (cont.)

Study Area 6 (Cont.) Species	Census Dates						
	11/12	1/27	2/18	3/4	3/31	5/27	
Carolina wren	5	1	1	4	2	1	
mockingbird	6	6	3	5	5	x	
brown thrasher		9	4	4	1		
robin	65	6	31	3			
hermit thrush	3	1	2		1		
eastern bluebird	17	6					
blue-gray gnatcatcher					4		
golden-crowned kinglet	6	1					
ruby-crowned kinglet	9	4	1	4	3		
cedar waxwing				16	7		
loggerhead shrike	7	2	1	3	1		
starling			6	1			
white-eyed vireo					1	3	
orange-crowned warbler	1						
myrtle warbler	2		1	13	24		
common yellowthroat						4	
yellow-breasted chat						9	
eastern meadowlark	125	11	31	24	7	2	
western meadowlark	1						
redwinged blackbird	1600	1425	2315	92	x	1	
rusty blackbird			20				

Appendix V-03. (cont.)

Study Area 6 (Cont.) Species	Census Dates						
	11/12	1/27	2/18	3/4	3/31	5/27	
common grackle	350	285	335	33	31	33	
brown-headed cowbird	30	110	535	11	8	20	
cardinal	31	53	18	36	23	38	
blue grosbeak						1	
indigo bunting						11	
painted bunting						17	
dickcissel						1	
purple finch	6		1				
American goldfinch	36	1					
rufous-sided towhee	2			1			
savannah sparrow	15	11	1	3	4		
LeConte's sparrow		3	1				
vesper sparrow	6	5					
slate-colored junco	2						
field sparrow	1		2	2			
white-crowned sparrow	12		3	2	7		
white-throated sparrow	20	5	2	8	13		
fox sparrow	10	20	8	3			
Lincoln's sparrow	5			4	4		
swamp sparrow	24	2	5	6	3		
song sparrow	35	16	13	9			

Appendix V-03. (cont.)

Study Area 6 (Cont.) Species	Census Dates					
	11/12	1/27	2/18	3/4	3/31	5/27	
Total Individuals	2617	2063	3401	344	183	307	
Total Census Species	5[illegible]	38	40	40	30	37	

Total Species All Censuses: 8 (plus 3 non-census species= 84).
Total Individuals All Censuses 8,915 (avg. 1,486 per census).

Appendix V-03. (cont.)

Study Area 7 Species	Census Dates						
	11/4	11/17	1/20	2/17	3/24	4/20	
great blue heron	1	x		2		1	
green heron						1	
little blue heron						1	
cattle egret						2	
snowy egret						1	
yellow-cr night heron						2	
white-fronted goose	5						
mallard			5	10			
pintail				2			
blue-winged teal						3	
wood duck	2	x	6	4	2	2	
turkey vulture	6	15		4	10	6	
black vulture		29		4	5		
white-tailed kite					2	2	
Mississippi kite						1	
sharp-shinned hawk		1				x	
Cooper's hawk						x	
red-tailed hawk	1	3					
red-shouldered hawk	1		1	2		2	
broad-winged hawk						x	
marsh hawk	2	2		1	1	2	

Appendix V-03. (cont.)

Study Area 7 (Cont.) Species	Census Dates						
	11/4	11/17	1/20	2/17	3/24	4/20	
American kestrel	x	2				x	
bobwhite						x	
killdeer	7	27	1	2	2	3	
common snipe	5					x	
upland sandpiper						x	
solitary sandpiper						x	
greater yellowlegs						1	
lesser yellowlegs						3	
mourning dove	6	12		3		3	
barn owl					x		
great horned owl						x	
barred owl	2	1	1	2		2	
common nighthawk						3	
chimney swift						8	
ruby-throated hummingbird						1	
belted kingfisher	1					1	
common flicker	7	22	[illegible]	11	1		
pileated woodpecker		1	1	1	1	1	
red-bellied woodpecker	7	13	7	11	5	7	
red-headed woodpecker	x					x	
yellow-bellied sapsucker	1	6	[illegible]	6			

Appendix V-03. (cont.)

Study Area 7 (Cont.) Species	Census Dates						
	11/4	11/17	1/20	2/17	3/24	4/20	
hairy woodpecker		2					
downy woodpecker	2	3	7	5	2	4	
eastern kingbird						x	
scissor-tailed flycatcher						1	
great crested flycatcher						1	
eastern phoebe	2	3	1	2			
tree swallow						1	
rough-winged swallow						5	
barn swallow						3	
purple martin					5	2	
blue jay	11	14	9	3	1	1	
common crow	22	57	19	25	12	29	
Carolina chickadee	15	39	31	23	13	13	
tufted titmouse	6	25	8	6	16	17	
white-breasted nuthatch	1						
brown creeper		8	1	2			
house wren		1					
winter wren	2	4	1	1			
Bewick's wren	3	3		1			
Carolina wren	12	29	23	33	12	17	
mockingbird	1	1	3	4	3	2	

Appendix V-03. (cont.)

Study Area 7 (Cont.) Species	Census Dates						
	11/4	11/17	1/20	2/17	3/24	4/20	
gray catbird	2						
brown thrasher	9	5	12	15		2	
robin	42	4	122	36			
hermit thrush	1	4	7	4	1		
eastern bluebird	1	8				x	
blue-gray gnatcatcher					6	2	
golden-crowned kinglet	6	10		2			
ruby-crowned kinglet	9	33	5	3	5	2	
water pipit	7	1	1				
cedar waxwing			32				
loggerhead shrike	3	1	1	1		x	
starling				2		2	
white-eyed vireo					5	6	
solitary vireo			1				
red-eyed vireo						2	
prothonotary warbler						2	
Swainson's warbler						2	
Tennessee warbler						1	
orange-crowned warbler	4	1	3	1			
Nashville warbler						1	
northern parula warbler					18	21	

Appendix V-03. (cont.)

Study Area 7 (Cont.) Species	Census Dates						
	11/4	11/17	1/20	2/17	3/24	4/20	
myrtle warbler	9	24	4	4			
pine warbler		1	2				
Kentucky warbler						3	
common yellowthroat						1	
house sparrow	x	x	x	x	x	x	
eastern meadowlark	23	35	3	6	6	7	
western meadowlark		1					
redwinged blackbird	2	240	13	35		5	
Brewer's blackbird		20					
common grackle	43	25	73	3	1	2	
brown-headed cowbird	400	x			2	32	
cardinal	48	58	97	71	44	92	
blue grosbeak						1	
indigo bunting						2	
painted bunting						2	
dickcissel						4	
purple finch		2					
pine siskin			10				
American goldfinch	12	18	4	3			
rufous-sided towhee		1					
savannah sparrow	1	20		11		2	

Appendix V-03. (cont.)

Study Area 7 (Cont.) Species	Census Dates						
	11/4	11/17	1/20	2/17	3/24	4/20	
grasshopper sparrow						x	
vesper sparrow	2	20		1			
lark sparrow						2	
slate-colored junco		6	7	4	2		
white-crowned sparrow		1		3		x	
white-throated sparrow	78	55	173	70	40	6	
fox sparrow			16	11			
Lincoln's sparrow		4			3	x	
swamp sparrow			1		1		
song sparrow		6	2	6	1		
Total Individuals	833	927	721	462	228	361	
Total Census Species	46	53	41	47	31	63	

Total Species All Censuses: 105 (plus 10 non-census species= 115).
Total Individuals All Censuses: 3,532 (avg. 589 per census).

Appendix V-03. (cont.)

Study Area 8 Species	Census Dates						
	10/21	11/7	12/9	1/3	3/23	4/1	4/29
pied-billed grebe	1		2		1	2	
double-crested cormorant						x	
anhinga	x				8	27	6
great blue heron		1	1	3	26	37	6
green heron							1
little blue heron	x	1			13	21	31
cattle egret	32	23		1			117
great egret					65	58	7
snowy egret					1	2	x
Louisiana heron						x	
black-cr night heron						x	
yellow-cr night heron					3	1	12
white ibis	1				1	x	129
snow/blue goose	x						
mallard	1	7	5	14	5	3	
gadwall			15	13	17	3	
pintail			4				
green-winged teal	3	5	7	23	5	2	
blue-winged teal	1				50	24	14
American wigeon	7	2	8	32	3		
northern shoveler	1	1	3				

Appendix V-03. (cont.)

Study Area 8 (Cont.) Species	Census Dates						
	10/21	11/7	12/9	1/3	3/23	4/1	4/29
wood duck	5	9	12	4	19	7	2
ring-necked duck			x				
turkey vulture	4	5	11	12		1	1
black vulture	2	3	5	9	61	39	45
Mississippi kite							x
sharp-shinned hawk	1						
Cooper's hawk		1				1	
red-tailed hawk	1	1	1	2			
red-shouldered hawk		2	1	4	2	1	x
broad-winged hawk						2	
marsh hawk	1						
American kestrel	x	2	2				
sora rail					1	1	
purple gallinule							2
common gallinule	1						3
American coot	2		7		x	15	x
killdeer	6	14	11	14			x
common snipe	12	1	6				
solitary sandpiper				1	1	2	4
ring-billed gull						x	
mourning dove	4	22	4	25	4	1	2

Appendix V-03. (cont.)

Study Area 8 (Cont.) Species	Census Dates						
	10/21	11/7	12/9	1/3	3/23	4/1	4/29
yellow-billed cuckoo							1
roadrunner							x
barred owl	2	1			3	1	1
chimney swift	1				65	12	30
ruby-throated hummingbird						2	2
belted kingfisher	1	1			1		
common flicker	4	11	11	18	1	1	
pileated woodpecker	2	4	2	3	1		2
red-bellied woodpecker	3	9	1	8	8	5	5
red-headed woodpecker	x	1					3
yellow-bellied sapsucker	1	1	1	5		1	
downy woodpecker	1	1	2	2	7	5	3
scissor-tailed flycatcher	14					1	x
eastern kingbird						1	6
great crested flycatcher							7
eastern phoebe	4	7	4	5			
acadian flycatcher							10
vermillion flycatcher	1						
rough-winged swallow					1		2
barn swallow	1						x
purple martin					2		x

Appendix V-03. (cont.)

Study Area 8 (Cont.) Species	Census Dates						
	10/21	11/7	12/9	1/3	3/23	4/1	4/29
blue jay	31	13	11	22	12	13	5
common crow	25	35	13	56	20	8	5
Carolina chickadee	6	7	9	17	20	10	14
tufted titmouse	2	4	5	2	23	9	12
white-breasted nuthatch							x
brown creeper		1	1				
house wren	2			1			
winter wren	x	1	1	1			
Carolina wren	4	2	11	18	21	5	7
long-billed marsh wren	3						
short-billed marsh wren	1		2				
mockingbird	3	2	3	7	2	3	
gray catbird	2						
brown thrasher	4	3	8	12	1	2	1
robin		5	169	340	24	1	
hermit thrush				2		1	
eastern bluebird		4	2				
blue-gray gnatcatcher	1		1		10	20	6
golden-crowned kinglet		5	4	3			
ruby-crowned kinglet	3	2	17	14	2	7	
water pipit			26	2			
cedar waxwing				12		12	

Appendix V-03. (cont.)

Study Area 8 (Cont.) Species	Census Dates						
	10/21	11/7	12/9	1/3	3/23	4/1	4/29
loggerhead shrike	2	6		3	1		x
starling	x	9			7	6	1
white-eyed vireo					3	14	7
yellow-throated vireo					1	1	2
solitary vireo			1	1			
red-eyed vireo							8
prothonotary warbler						2	6
Swainson's warbler							2
Tennessee warbler							6
orange-crowned warbler			4	2	1	2	
northern parula warbler					17	20	14
myrtle warbler			9	17	54	17	
yellow-throated warbler					2	2	1
pine warbler			1				
northern waterthrush							1
Louisiana waterthrush					1		
Kentucky warbler							3
common yellowthroat	3	1		2		2	3
yellow-breasted chat							1
hooded warbler						3	2
Wilson's warbler	1						

Appendix V-03. (cont.)

Study Area 8 (Cont.) Species	Census Dates						
	10/21	11/7	12/9	1/3	3/23	4/1	4/29
eastern meadowlark	1	40		32	3	1	x
redwinged blackbird	1	4	48	290	40	8	5
Baltimore oriole							1
rusty blackbird			5	25	1		
Brewer's blackbird				x	x		
brown-headed cowbird	6	10		15	4	16	6
summer tanager							4
cardinal	24	21	61	42	31	64	34
indigo bunting	3						2
painted bunting							7
evening grosbeak				2			
purple finch			2	23			
American goldfinch			24	13		11	1
rufous-sided towhee			6	2			
savannah sparrow		4	2	7	11		1
vesper sparrow			12	2			
slate-colored junco			5				
chipping sparrow					2		
field sparrow			2			1	
white-crowned sparrow		x					
white-throated sparrow	2	6	91	43	17	17	6

Appendix V-03. (cont.)

Study Area 8 (Cont.) Species	Census Dates						
	10/21	11/7	12/9	1/3	3/23	4/1	4/29
fox sparrow				1			
Lincoln's sparrow	2						
swamp sparrow	4	2	3	9	9	1	
song sparrow		2	3	7	2		
Total Individuals	257	325	688	1245	717	558	628
Total Census Species	55	60	57	55	57	60	59

Total Species All Censuses: 120 (plus 12 non-census species= 132).
Total Individuals All Censuses: 4,418 (avg. 631 per census).

Appendix V-03. (cont.)

Study Area 9 Species	Census Dates						
	9/16	10/28	2/10	2/24	3/10	4/14	4/28
double-crested cormorant			x		1	x	
anhinga	1		x			2	17
great blue heron			2	x	x	x	4
little blue heron	x		x		x	2	1
cattle egret	x						10
great egret			x	x	1	x	11
snowy egret	x					x	
yellow-cr night heron					1	1	1
white ibis			x				
mallard			x		x		
green-winged teal			x				
American wigeon			x				
wood duck			2	4			2
turkey vulture	2	6		4	4	4	
black vulture	1		12		x	x	
sharp-shinned hawk			x				
Cooper's hawk		x					x
red-tailed hawk	1						
red-shouldered hawk	2		1	2	2	3	1
broad-winged hawk	36						
American kestrel				x	x		

Appendix V-03. (cont.)

Study Area 9 (Cont.) Species	Census Dates						
	9/16	10/28	2/10	2/24	3/10	4/14	4/28
killdeer	x			x	1		
spotted sandpiper	x		x			x	x
Caspian tern					x		
yellow-billed cuckoo	3						4
barred owl	1		2	5		1	2
chimney swift							6
ruby-throated himmingbird	1					2	2
belted kingfisher	2		x		x	x	
common flicker		5	2	8	6		
pileated woodpecker	4	4	3	5	2	2	3
red-bellied woodpecker	4	6	10	17	5	5	7
red-headed woodpecker			x	2			
yellow-bellied sapsucker		14	13	14	4		
hairy woodpecker	1						
downy woodpecker	3	5	3	12	1	5	3
eastern kingbird						x	x
scissor-tailed flycatcher		x					
great crested flycatcher	5						5
eastern phoebe		11	1	2	1		
acadian flycatcher	13						9
eastern wood pewee	1	1					

Appendix V-03. (cont.)

Study Area 9 (Cont.) Species	Census Dates						
	9/16	10/28	2/10	2/24	3/10	4/14	4/28
tree swallow					15		
rough-winged swallow	x	x			2	x	
barn swallow					2		
purple martin					7		
blue jay		31	11	17	17	8	8
common crow	10	9	11	9	5	5	7
Carolina chickadee	31	24	27	16	20	18	18
tufted titmouse	14	25	24	24	13	13	20
brown creeper		4	3	1			
winter wren		1	1	1			
Carolina wren	23	8	17	35	13	6	11
mockingbird				x	1		
gray catbird	1						3
brown thrasher		16	19	12	4	4	[illegible]
robin			10	2	3		
wood thrush		3					1
hermit thrush		1	4	8	1		
Swainson's thrush	1						3
eastern bluebird			x	x			
blue-gray gnatcatcher	7	5				12	2
golden-crowned kinglet		13	5	1			

Appendix V-03. (cont.)

Study Area 9 (Cont.) Species	Census Dates						
	9/16	10/28	2/10	2/24	3/10	4/14	4/28
ruby-crowned kinglet		36	3	4	2	1	
cedar waxwing						26	
loggerhead shrike	x			x			
white-eyed vireo	78	2	1		1	27	16
yellow-throated vireo	1					2	1
solitary vireo			1	1			
red-eyed vireo						7	9
black & white warbler	1	1	1				1
prothonotary warbler	3					12	11
Swainson's warbler	1						3
worm-eating warbler	1						1
Tennessee warbler							12
orange-crowned warbler		3	5	2			
northern parula warbler	4				12	39	16
myrtle warbler		9	18	17	4	8	1
black-throated green warbler		2					1
yellow-throated warbler							1
chestnut-sided warbler							1
ovenbird	1						
northern waterthrush	4						1
Kentucky warbler						4	6
common yellowthroat						x	

Appendix V-03. (cont.)

Study Area 9 (Cont.) Species	Census Dates						
	9/16	10/28	2/10	2/24	3/10	4/14	4/28
yellow-breasted chat	2						
hooded warbler	6					9	
Canada warbler	1						
American redstart							12
redwinged blackbird				x	1	1	
Baltimore oriole							1
brown-headed cowbird						2	13
summer tanager	1						2
cardinal	54	78	69	53	49	72	63
indigo bunting						1	24
painted bunting							6
purple finch				5			
American goldfinch			3	16	25		3
rufous-sided towhee			6		1		
savannah sparrow						x	
slate-colored junco			x	x			
white-throated sparrow		11	335	36	78	31	5
fox sparrow			3				
Total Individuals	326	334	628	325	305	335	384
Total Census Species	39	28	33	30	34	32	53

Total Species All Censuses: 86 (plus 17 non-census species = 103).
Total Individuals All Censuses: 2,637 (avg. 377 per census).

Appendix V-03. (cont.)

Study Area 10 Species	Census Dates						
	12/10	2/11	3/11	4/15	5/13		
double-crested cormorant		585	14	3			
anhinga		1	3		2		
great blue heron		1	6	3	1		
little blue heron			1	1	2		
cattle egret				14	2		
great egret	2		5	6			
snowy egret			2		7		
Louisiana heron			1	1	4		
yellow-cr night heron					1		
white ibis			360		48		
Canada goose			x				
wood duck		8	3				
turkey vulture	3	8					
black vulture	9	11	3	1	1		
Mississippi kite					1		
red-tailed hawk	1		1				
red-shouldered hawk		2	2	2	1		
marsh hawk		1					
American kestrel		1					
ring-billed gull			1				
mourning dove			2				

Appendix V-03. (cont.)

Study Area 10 (Cont.) Species	Census Dates						
	12/10	2/11	3/11	4/15	5/13		
yellow-billed cuckoo					6		
barred owl		2	1	2	1		
chimney swift				4	1		
ruby-throated hummingbird				2			
belted kingfisher		1					
common flicker	4	4					
pileated woodpecker	1	1	3	1			
red-bellied woodpecker		6	8	4	4		
red-headed woodpecker		4	3				
yellow-bellied sapsucker	1	3	3				
hairy woodpecker		1					
downy woodpecker	2	3	5	5	3		
great crested flycatcher					4		
eastern phoebe	4	1	1				
yellow-bellied flycatcher					1		
eastern wood pewee				2	1		
tree swallow			7				
bank swallow					11		
barn swallow				2	27		
cliff swallow					2		
purple martin			5	6			

Appendix V-03. (cont.)

Study Area 10 (Cont.) Species	Census Dates						
	12/10	2/11	3/11	4/15	5/13		
blue jay	11	15	29	6	5		
common crow	10	9	6	3	6		
Carolina chickadee	15	24	21	13	16		
tufted titmouse	2	4	4	11	13		
brown creeper	1	1					
house wren	1	4					
Carolina wren	6	11	15	6	7		
mockingbird	8	17	7	7	2		
brown thrasher	3	17	8	3			
robin	65	28	2				
wood thrush				4			
hermit thrush	3	3					
eastern bluebird	34	10	4				
blue-gray gnatcatcher	2			3			
ruby-crowned kinglet	24	8	12	2			
loggerhead shrike	2	1	1				
white-eyed vireo			3	14	7		
solitary vireo	1						
red-eyed vireo				2	5		
black & white warbler				5			
prothonotary warbler				3	3		

Appendix V-03. (cont.)

Study Area 10 (Cont.) Species	Census Dates						
	12/10	2/11	3/11	4/15	5/13		
Swainson's warbler				1	2		
worm-eating warbler				1			
blue-winged warbler				1			
Tennessee warbler				13			
orange-crowned warbler	2	4	2				
northern parula warbler			6	8	8		
magnolia warbler					1		
myrtle warbler	13	9	4				
cerulean warbler				2			
blackburnian warbler				1			
yellow-throated warbler			1				
chestnut-sided warbler				1			
pine warbler	4	2	1	1	1		
Kentucky warbler				5	3		
common yellowthroat			1	6	2		
hooded warbler				5			
American redstart				1			
redwinged blackbird	2	5	6				
orchard oriole				36			
Baltimore oriole				2			
common grackle	30	1	3				

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ECOLOGICAL SURVEY DATA FOR ENVIRONMENTAL CONSIDERATIONS ON THE --ETC(U)
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Appendix V-03. (cont.)

Study Area 10 (Cont.) Species	Census Dates						
	12/10	2/11	3/11	4/15	5/13		
brown-headed cowbird			1	4	20		
scarlet tanager				1			
summer tanager				1	2		
cardinal	44	69	82	38	41		
indigo bunting	1			12	13		
painted bunting				1	10		
American goldfinch	31	53	14				
rufous-sided towhee	1	2	1	1			
savannah sparrow		5					
Henslow's sparrow		2					
LeConte's sparrow		1					
slate-colored junco		36					
field sparrow	4	2	2				
white-throated sparrow	87	276	55	26			
fox sparrow		3					
Lincoln's sparrow		5		2			
swamp sparrow	3	11	1				
song sparrow	1	2					
Total Individuals	438	1284	732	311	298		
Total Census Species	33	51	50	55	42		

Total Species All Censuses: 101 (plus 1 non-census species= 102).
Total Individuals All Censuses: 3,063 (avg. 613 per census).

Appendix V-04. Common and scientific names of all birds recorded at ten Trinity River transects, followed respectively by the maximum number of individuals counted on any single census and the number of different censuses each was observed[1]

Species	Transect Number (no. of censuses in parentheses)									
	1(7)	2(5)	3(5)	4(5)	5(6)	6(6)	7(6)	8(7)	9(7)	10(5)
pied-billed grebe _Podilymbus podiceps_		x						2 (4)		
white pelican _Pelecanus erythrorhynchos_			33 (1)							
double-crested cormorant _Phalacrocorax auritus_		x	x					x	1 (1)	585 (3)
anhinga _Anhinga anhinga_								27 (3)	17 (3)	3 (3)
great blue heron Ardea _herodias_		4 (3)	x	1 (1)		2 (2)	2 (3)	37 (6)	4 (2)	6 (4)
green heron _Butorides virescens_	x			x	1 (1)	1 (1)	1 (1)	1 (1)		
little blue heron _Florida caerulea_	1 (1)	6 (1)	10 (1)	28 (2)	1 (1)	9 (1)	1 (1)	31 (4)	2 (2)	2 (3)
cattle egret _Bubulcus ibis_	2 (2)	9 (1)	3 (1)	30 (2)	10 (1)	81 (1)	2 (1)	117 (4)	10 (1)	14 (2)
great egret Casmerodius _albus_				x		1 (2)		65 (3)	11 (2)	6 (3)
snowy egret _Egretta thula_	1 (1)		x	x			1 (1)	2 (2)	x	7 (2)
Louisiana heron _Hydranassa tricolor_								x		4 (3)
black-crowned night heron _Nycticorax nycticorax_								x		
yellow-crowned night heron _Nyctanassa violacea_	1 (1)	1 (1)			1 (1)		2 (1)	12 (3)	1 (3)	1 (1)

Appendix V-04. (cont.)

Species	Transect Number (no. of censuses in parentheses)									
	1(7)	2(5)	3(5)	4(5)	5(6)	6(6)	7(6)	8(7)	9(7)	10(5)
American bittern *Botaurus lentiginosus*				1 (1)						
wood stork *Mycteria americana*			140 (1)							
white ibis *Eudocimus albus*								129 (3)	x	360 (2)
Canada goose *Branta canadensis*		x		x						x
white-fronted goose *Anser albifrons*							5 (1)			
snow/blue goose *Chen caerulescens*								x		
mallard *Anas platyrhynchos*		x	2 (1)	8 (2)			10 (2)	14 (6)	x	
gadwall *Anas strepera*		4 (1)						17 (4)		
pintail *Anas acuta*		x					2 (1)	4 (1)		
green-winged teal *Anas crecca*		x						23 (6)	x	
blue-winged teal *Anas discors*		21 (1)	x	x			3 (1)	50 (4)		
American wigeon *Anas americana*								32 (5)	x	
northern shoveler *Anas clypeata*		x						3 (3)		

Appendix V-04. (cont.)

Species	Transect Number (no. of censuses in parentheses)									
	1(7)	2(5)	3(5)	4(5)	5(6)	6(6)	7(6)	8(7)	9(7)	10(5)
wood duck Aix sponsa	2 (2)	6 (4)		4 (3)		x	6 (5)	19 (7)	4 (3)	8 (2)
ring-necked duck Aythya collaris		x						x		
canvasback Aythya valisineria		x								
lesser scaup Aythya affinis		x								
ruddy duck Oxyura jamaicensis		x								
hooded merganser Lophodytes cucullatus				1 (1)		2 (1)				
turkey vulture Cathartes aura	1 (2)	1 (1)	23 (5)	9 (5)	8 (6)	14 (5)	15 (5)	11 (6)	6 (5)	8 (2)
black vulture Coragyps atratus				6 (1)	3 (1)		29 (3)	61 (7)	12 (2)	11 (3)
white-tailed kite Elanus leucurus							2 (2)			
Mississippi kite Ictinia misisippiensis							1 (1)	x		1 (1)
sharp-shinned hawk Accipiter striatus			1 (1)	2 (2)		x	1 (1)	1 (1)	x	
Cooper's hawk Accipiter cooperii			x				x	1 (2)	x	
red-tailed hawk Buteo jamaicensis	4 (4)	1 (3)	2 (2)	2 (2)	5 (3)	5 (6)	[illegible]	2 (4)	1 (1)	1 (2)

Appendix V-04. (cont.)

Species	Transect Number (no. of censuses in parentheses)									
	1(7)	2(5)	3(5)	4(5)	5(6)	6(6)	7(6)	8(7)	9(7)	10(5)
red-shouldered hawk *Buteo lineatus*			4 (4)	1 (3)		1 (3)	2 (4)	4 (5)	3 (6)	2 (4)
broad-winged hawk *Buteo platypterus*			21 (1)				x	2 (1)	36 (1)	
Swainson's hawk *Buteo swainsoni*	1 (1)	1 (1)	2 (2)	1 (1)						
rough-legged hawk *Buteo lagopus*	1 (1)									
bald eagle *Haliaetus leucocephalus*				2 (1)						
marsh hawk *Circus cyaneus*	1 (1)	x	x		2 (2)	2 (5)	2 (5)	1 (1)		1 (1)
osprey *Pandion haliaetus*		x								
peregrine falcon *Falco peregrinus*			x							
American kestrel *Falco sparverius*	1 (1)	x	3 (1)	1 (1)	1 (2)	1 (4)	2 (1)	2 (2)	x	1 (1)
bobwhite *Colinus virginianus*	20 (3)	x	14 (2)		15 (3)	18 (1)	2 (1)			
sora rail *Porzana carolina*								1 (2)		
purple gallinule *Porphyrula martinica*								2 (1)		
common gallinule *Gallinula chloropus*								3 (2)		

Appendix V-04. (cont.)

Species	Transect Number (no. of censuses in parentheses)									
	1(7)	2(5)	3(5)	4(5)	5(6)	6(6)	7(6)	8(7)	9(7)	10(5)
American coot _Fulica americana_		x						15 (3)		
semipalmated plover _Charadrius semipalmatus_			x							
piping plover _Charadrius melodus_			x							
killdeer _Charadrius vociferus_	3 (4)	1 (1)	2 (3)	7 (3)	3 (4)	3 (5)	27 (6)	14 (4)	1 (1)	
golden plover _Pluvialis dominica_			x							
American woodcock _Philohela minor_			1 (2)		1 (1)					
common snipe _Capella gallinago_						1 (1)	5 (1)	12 (3)		
whimbrel _Numenius phaeopus_			x							
upland sandpiper _Bartramia longicauda_	5 (1)		x				x			
spotted sandpiper _Actitis macularia_	1 (1)		x						x	
solitary sandpiper _Tringa solitaria_	1 (1)		1 (1)	x			x	4 (4)		
greater yellowlegs _Tringa melanoleucus_			x			2 (1)	1 (1)			
lesser yellowlegs _Tringa flavipes_			x				[illegible] (1)			

Appendix V-04. (cont.)

Species	Transect Number (no. of censuses in parentheses)									
	1(7)	2(5)	3(5)	4(5)	5(6)	6(6)	7(6)	8(7)	9(7)	10(5)
willet *Catoptrophorus semipalmatus*			x							
pectoral sandpiper *Calidris melanotos*			x							
white-rumped sandpiper *Calidris fuscicollis*			x	x						
Baird's sandpiper *Calidris bairdii*			x							
least sandpiper *Calidris minutilla*			x	x						
semipalmated sandpiper *Calidris pusillus*			x	x						
dunlin *Calidris alpina*			x							
long-billed dowitcher *Limnodromus scolopaceus*			x							
stilt sandpiper *Micropalama himantopus*			x							
buff-breasted sandpiper *Tryngites subruficollis*			x		7 (1)					
Hudsonian godwit *Limosa haemastica*			x							
Wilson's phalarope *Steganopus tricolor*			x							
ring-billed gull *Larus delawarensis*		1 (1)		1 (1)				x		1 (1)

Appendix V-04. (cont.)

Species	Transect Number (no. of censuses in parentheses)									
	1(7)	2(5)	3(5)	4(5)	5(6)	6(6)	7(6)	8(7)	9(7)	10(5)
Franklin's gull *Larus pipixcan*	14 (2)	1 (1)	4 (1)	20 (1)						
Caspian tern *Hydroprogne caspia*									x	
black tern *Chlidonias niger*			x							
mourning dove *Zenaida macroura*	14 (7)	4 (1)	5 (4)	7 (3)	45 (6)	7 (4)	12 (4)	25 (7)		2 (1)
yellow-billed cuckoo *Coccyzus americanus*			4 (1)	2 (1)		5 (1)		1 (1)	4 (2)	6 (1)
roadrunner *Geococcyx californianus*				x				x		
barn owl *Tyto alba*						1 (1)	x			
screech owl *Otus asio*				1 (1)	1 (1)					
great horned owl *Bubo virginianus*	x		1 (2)	2 (1)	1 (1)		x			
barred owl *Strix varia*	2 (2)	1 (1)	4 (3)	4 (5)	4 (1)	2 (2)	2 (5)	3 (5)	5 (5)	2 (4)
chuck-will's-widow *Caprimulgus carolinensis*	x			x						
common nighthawk *Chordeiles minor*			2 (1)	x			3 (1)			
chimney swift *Chaetura pelagica*	32 (4)	17 (2)	15 (2)	1 (1)	14 (2)		8 (1)	65 (4)	6 (1)	4 (2)

Appendix V-04. (cont.)

Species	Transect Number (no. of censuses in parentheses)									
	1(7)	2(5)	3(5)	4(5)	5(6)	6(6)	7(6)	8(7)	9(7)	10(5)
ruby-throated hummingbird *Archilochus colubris*	1 (1)	1 (1)	2 (1)	1 (1)	4 (1)	2 (1)	1 (1)	2 (2)	2 (3)	2 (1)
black-chinned hummingbird *Archilochus alexandri*	2 (1)									
belted kingfisher *Megaceryle alcyon*	1 (1)			1 (1)			1 (2)	1 (3)	2 (1)	1 (1)
common flicker *Colaptes auratus*	18 (2)	4 (4)	22 (4)	28 (3)	10 (4)	17 (4)	22 (5)	18 (6)	8 (4)	4 (2)
pileated woodpecker *Dryocopus pileatus*		x	2 (4)	4 (5)	x		1 (5)	4 (6)	5 (7)	3 (4)
red-bellied woodpecker *Centurus carolinus*	7 (6)	14 (5)	12 (5)	13 (5)	3 (5)	9 (6)	13 (6)	9 (7)	17 (7)	8 (4)
red-headed woodpecker *Melanerpes erythrocephalus*	1 (1)			2 (2)		1 (1)	x	3 (2)	2 (1)	4 (2)
yellow-bellied sapsucker *Sphyrapicus varius*	1 (2)	1 (2)	3 (3)	9 (3)	1 (1)	2 (4)	6 (4)	5 (5)	14 (4)	3 (3)
hairy woodpecker *Dendrocopos villosus*	2 (2)	1 (2)	2 (3)	4 (1)	1 (1)		2 (1)		1 (1)	1 (1)
downy woodpecker *Dendrocopos pubescens*	4 (5)	13 (5)	10 (5)	12 (5)	7 (4)	7 (6)	7 (6)	7 (7)	12 (7)	5 (5)
ladder-backed woodpecker *Dendrocopos scalaris*	1 (1)									
eastern kingbird *Tyrannus tyrannus*	1 (2)		2 (1)	2 (1)	2 (1)		x	6 (2)	x	
western kingbird *Tyrannus verticalis*		x	x							

Appendix V-04. (cont.)

Species	Transect Number (no. of censuses in parentheses)									
	1(7)	2(5)	3(5)	4(5)	5(6)	6(6)	7(6)	8(7)	9(7)	10(5)
scissor-tailed flycatcher <u>Muscivora forficata</u>	1 (2)	x	24 (2)	1 (1)	4 (2)	2 (1)	1 (1)	14 (2)	x	
great crested flycatcher <u>Myiarchus crinitus</u>	3 (2)	6 (1)	3 (1)	5 (1)	1 (1)	1 (1)	1 (1)	7 (1)	5 (2)	4 (1)
eastern phoebe <u>Sayornis phoebe</u>	1 (2)	1 (1)	2 (2)	3 (2)	1 (1)	3 (2)	3 (4)	7 (4)	11 (4)	4 (3)
yellow-bellied flycatcher <u>Empidonax flaviventris</u>										1 (1)
acadian flycatcher <u>Empidonax virescens</u>			2 (1)	2 (1)				10 (1)	13 (2)	
willow flycatcher <u>Empidonax traillii</u>						3 (1)				
least flycatcher <u>Empidonax minimus</u>	2 (2)	1 (1)	1 (1)	1 (1)						
eastern wood pewee <u>Contopus virens</u>	1 (1)		1 (1)	4 (1)	2 (1)	x			1 (2)	[illegible] (2)
olive-sided flycatcher <u>Nuttallornis borealis</u>			2 (2)							
vermillion flycatcher <u>Pyrocephalus rubinus</u>								1 (1)		
horned lark <u>Eremophila alpestris</u>		2 (1)	x		3 (2)					
tree swallow <u>Iridoprocne bicolor</u>	15 (1)		25 (1)				1 (1)		15 (1)	7 (1)
bank swallow <u>Riparia riparia</u>	1 (1)									11 (1)

Appendix V-04. (cont.)

Species	Transect Number (no. of censuses in parentheses)									
	1(7)	2(5)	3(5)	4(5)	5(6)	6(6)	7(6)	8(7)	9(7)	10(5)
rough-winged swallow <u>Stelgidopteryx ruficollis</u>	2 (1)	2 (2)	2 (1)				5 (1)	2 (2)	2 (1)	
barn swallow <u>Hirundo rustica</u>	38 (2)	x	120 (2)	1 (2)	3 (1)	2 (1)	3 (1)	1 (1)	2 (1)	27 (2)
cliff swallow <u>Petrochelidon pyrrhonota</u>	14 (2)	x	3 (2)							2 (1)
purple martin <u>Progne subis</u>		x				3 (1)	5 (2)	2 (1)	7 (1)	6 (2)
blue jay <u>Cyanocitta cristata</u>	37 (7)	27 (5)	85 (5)	6 (5)	7 (5)	20 (6)	14 (6)	31 (7)	31 (6)	29 (5)
common crow <u>Corvus brachyrhynchos</u>	31 (7)	30 (5)	20 (5)	36 (5)	24 (6)	72 (6)	57 (6)	56 (7)	11 (7)	10 (5)
Carolina chickadee <u>Parus carolinensis</u>	27 (7)	17 (5)	39 (5)	43 (5)	9 (6)	16 (6)	39 (6)	20 (7)	31 (7)	[illegible]
tufted titmouse <u>Parus bicolor</u>	18 (7)	24 (5)	17 (5)	34 (5)	15 (6)	10 (6)	25 (6)	23 (7)	25 (7)	13 (5)
white-breasted nuthatch <u>Sitta carolinensis</u>				6 (5)			1 (1)	x		
brown creeper <u>Certhia familiaris</u>	1 (2)	1 (3)	1 (2)	7 (2)	1 (1)	2 (1)	8 (3)	1 (2)	4 (3)	1 (2)
house wren <u>Troglodytes aedon</u>	2 (2)		1 (1)		1 (1)	1 (1)	1 (1)	2 (2)		4 (2)
winter wren <u>Troglodytes troglodytes</u>				5 (1)		2 (1)	4 (4)	1 (3)	1 (3)	
Bewick's wren <u>Thryomanes bewickii</u>	5 (5)	x	1 (1)	1 (1)	2 (3)	1 (3)	3 (3)			

Appendix V-04. (cont.)

Species	Transect Number (no. of censuses in parentheses)									
	1(7)	2(5)	3(5)	4(5)	5(6)	6(6)	7(6)	8(7)	9(7)	10(5)
Carolina wren *Thryothorus ludovicianus*	9 (7)	25 (5)	8 (5)	8 (5)	9 (6)	5 (6)	33 (6)	21 (7)	35 (7)	15 (5)
long-billed marsh wren *Telmatodytes palustris*								3 (1)		
short-billed marsh wren *Cistothorus platensis*								2 (2)		
mockingbird *Mimus polyglottos*	7 (4)	1 (1)	3 (4)	4 (3)	16 (6)	6 (5)	4 (6)	7 (6)	1 (1)	17 (5)
gray catbird *Dumetella carolinensis*	x		3 (1)				2 (1)	2 (1)	3 (2)	
brown thrasher *Toxostoma rufum*	7 (4)	3 (4)	5 (4)	4 (5)	5 (5)	9 (4)	15 (5)	12 (7)	19 (6)	17 (4)
robin *Turdus migratorius*	218 (2)	74 (4)	180 (3)	68 (1)	41 (3)	65 (4)	122 (4)	340 (5)	10 (3)	65 (3)
wood thrush *Catharus mustelina*									3 (2)	[illegible] (1)
hermit thrush *Catharus guttata*	3 (3)	1 (1)	6 (3)	8 (3)	6 (3)	3 (4)	7 (5)	2 (2)	8 (4)	3 (2)
Swainson's thrush *Catharus ustulata*	3 (2)	1 (1)	6 (1)	1 (1)	1 (1)				3 (1)	
eastern bluebird *Sialia sialis*	14 (2)	3 (1)	2 (1)	18 (4)	5 (3)	17 (2)	8 (2)	4 (2)	x	34 (3)
blue-gray gnatcatcher *Polioptila caerulea*	4 (2)	6 (2)	4 (1)	8 (2)		4 (1)	6 (2)	20 (5)	12 (4)	3 (2)
golden-crowned kinglet *Regulus satrapa*	4 (1)		6 (3)	14 (2)	1 (1)	6 (2)	10 (3)	5 (3)	13 (3)	

Appendix V-04. (cont.)

Species	Transect Number (no. of censuses in parentheses)									
	1(7)	2(5)	3(5)	4(5)	5(6)	6(6)	7(6)	8(7)	9(7)	10(5)
ruby-crowned kinglet *Regulus calendula*	11 (5)	8 (5)	11 (4)	22 (4)	6 (4)	9 (5)	33 (6)	17 (6)	36 (5)	24 (4)
water pipit *Anthus spinoletta*			x	x			7 (3)	26 (2)		
Sprague's pipit *Anthus spragueii*			x		1 (1)					
cedar waxwing *Bombycilla cedrorum*	84 (4)	32 (2)	152 (1)	28 (2)	25 (2)	16 (2)	32 (1)	12 (2)	26 (1)	
loggerhead shrike *Lanius ludovicianus*	4 (3)	x	8 (3)	2 (4)	2 (6)	7 (5)	3 (4)	6 (4)	x	2 (3)
starling *Sturnus vulgaris*	84 (6)	68 (4)	7 (2)	575 (2)	140 (1)	6 (2)	2 (2)	9 (4)		
white-eyed vireo *Vireo griseus*	2 (2)	2 (2)	5 (1)	3 (2)		3 (2)	6 (2)	14 (3)	78 (6)	14 (3)
yellow-throated vireo *Vireo flavifrons*				2 (2)				2 (3)	2 (3)	
solitary vireo *Vireo solitarius*	3 (1)	1 (1)		1 (1)			1 (1)	1 (2)	1 (2)	1 (1)
red-eyed vireo *Vireo olivaceus*	4 (2)		9 (1)	5 (1)			2 (1)	8 (1)	9 (2)	5 (2)
Philadelphia vireo *Vireo philadelphicus*			1 (1)							
warbling vireo *Vireo gilvus*		2 (1)	2 (1)	1 (1)						
black & white warbler *Mniotilta variata*	1 (1)	1 (1)	3 (2)		1 (1)				1 (4)	5 (1)

Appendix V-04. (cont.)

Species	Transect Number (no. of censuses in parentheses)									
	1(7)	2(5)	3(5)	4(5)	5(6)	6(6)	7(6)	8(7)	9(7)	10(5)
prothonotary warbler *Protonotaria citrea*	2 (1)						2 (1)	6 (2)	12 (3)	3 (2)
Swainson's warbler *Limnothlypis swainsonii*							2 (1)	2 (1)	3 (2)	2 (2)
worm-eating warbler *Helmitheros vermivorus*									1 (2)	1 (1)
blue-winged warbler *Vermivora pinus*										1 (1)
Tennessee warbler *Vermivora peregrina*	2 (2)	5 (1)	2 (1)	3 (1)			1 (1)	6 (1)	12 (1)	13 (1)
orange-crowned warbler *Vermivora celata*	4 (3)		1 (2)		1 (1)	1 (1)	4 (4)	4 (4)	5 (3)	4 (3)
Nashville warbler *Vermivora ruficapilla*	35 (2)	19 (1)	3 (1)	1 (1)	9 (1)		1 (1)			
northern parula warbler *Parula americana*	1 (1)		1 (1)				21 (2)	20 (3)	39 (4)	8 (3)
yellow warbler *Dendroica petechia*	8 (1)	2 (1)		2 (1)						
magnolia warbler *Dendroica magnolia*			1 (1)	1 (1)						1 (1)
myrtle warbler *Dendroica coronata*	4 (4)	24 (5)	15 (3)	6 (2)	8 (5)	24 (4)	24 (4)	54 (4)	18 (6)	13 (3)
black-throated green warbler *Dendroica virens*	2 (1)								2 (2)	
cerulean warbler *Dendroica cerulea*										2 (1)

Appendix V-04. (cont.)

Species	Transect Number (no. of censuses in parentheses)									
	1(7)	2(5)	3(5)	4(5)	5(6)	6(6)	7(6)	8(7)	9(7)	10(5)
blackburnian warbler *Dendroica fusca*				3 (1)						1 (1)
yellow-throated warbler *Dendroica dominica*				3 (2)				2 (3)	1 (1)	1 (1)
chestnut-sided warbler *Dendroica pensylvanica*	1 (1)								1 (1)	1 (1)
bay-breasted warbler *Dendroica castanea*			2 (1)							
pine warbler *Dendroica pinus*							2 (2)	1 (1)		4 (5)
ovenbird *Seiurus aurocapillus*			1 (1)	1 (1)					1 (1)	
northern waterthrush *Seiurus noveboracensis*		1 (1)						1 (1)	4 (2)	
Louisiana waterthrush *Seiurus motacilla*								1 (1)		
Kentucky warbler *Oporornis formosus*			4 (1)				3 (1)	3 (1)	6 (2)	5
common yellowthroat *Geothlypis trichas*	3 (3)	2 (1)	1 (2)			4 (1)	1 (1)	3 (5)	x	6 (3)
yellow-breasted chat *Icteria virens*	6 (1)		1 (1)			9 (1)		1 (1)	6 (2)	
hooded warbler *Wilsonia citrina*								3 (2)	9 (3)	5 (1)
Wilson's warbler *Wilsonia pusilla*	10 (1)							1 (1)		

Appendix V-04. (cont.)

Species	Transect Number (no. of censuses in parentheses)									
	1(7)	2(5)	3(5)	4(5)	5(6)	6(6)	7(6)	8(7)	9(7)	10(5)
Canada warbler *Wilsonia canadensis*									1 (1)	
American redstart *Setophaga ruticilla*	3 (1)		1 (1)						12 (1)	1 (1)
house sparrow *Passer domesticus*	30 (4)	x	x	x	x		x	x		
bobolink *Dolichonyx oryzivorus*			x							
eastern meadowlark *Sturnella magna*	4 ([illegible])	x	4 ([illegible])	3 (1)	80 (6)	125 (6)	35 (6)	40 (5)		
western meadowlark *Sturnella neglecta*		x				1 (1)	1 (1)			
yellow-headed blackbird *Xanthocephalus xanthocephalus*			x							
redwinged blackbird *Agelaius phoeniceus*	36 (2)	210 (5)	40 (4)	1750 (2)	1000 (4)	2315 (5)	240 (5)	290 (7)	1 (2)	6 (3)
orchard oriole *Icterus spurius*	1 (1)		3 (1)		4 (1)					36 (1)
Baltimore oriole *Icterus galbula*		1 (1)	1 (1)					1 (1)	1 (1)	2 (1)
rusty blackbird *Euphagus carolinus*		9 (2)	11 (1)			20 (1)		25 (3)		
Brewer's blackbird *Euphagus cyanocephalus*							20 (1)	x		
great-tailed grackle *Cassidix mexicanus*	18 (3)	33 (2)								

Appendix V-04 (cont.)

Species	Transect Number (no. of censuses in parentheses)									
	1(7)	2(5)	3(5)	4(5)	5(6)	6(6)	7(6)	8(7)	9(7)	10(5)
common grackle *Quiscalus quiscula*	40 (3)	155 (4)	45 (4)	108 (4)	6 (4)	350 (6)	73 (6)			30 (3)
brown-headed cowbird *Molothrus ater*	65 (6)	14 (4)	75 (3)	22 (5)	44 (5)	535 (6)	400 (3)	16 (6)	13 (2)	20 (3)
scarlet tanager *Piranga olivacea*										1 (1)
summer tanager *Piranga rubra*			4 (1)	7 (2)				4 (1)	2 (2)	2 (2)
cardinal *Cardinalis cardinalis*	73 (7)	89 (5)	77 (5)	103 (5)	48 (6)	53 (6)	97 (6)	64 (7)	78 (7)	82 (5)
blue grosbeak *Guiraca caerulea*						1 (1)	1 (1)			
indigo bunting *Passerina cyanea*	9 (2)	1 (1)	25 (2)	3 (1)	1 (1)	11 (1)	2 (1)	3 (2)	24 (1)	13 (3)
painted bunting *Passerina ciris*	19 (2)		8 (1)	13 (1)		17 (1)	2 (1)	7 (1)	6 (1)	10 (2)
dickcissel *Spiza americana*	21 (1)	x	75 (1)		2 (1)	1 (1)	4 (1)			
evening grosbeak *Hesperiphona vespertina*								2 (1)		
purple finch *Carpodacus purpureus*	16 (1)	19 (3)	1 (1)	85 (2)	17 (3)	6 (2)	2 (1)	23 (2)	5 (1)	
pine siskin *Spinus pinus*	4 (1)			8 (1)	x		10 (1)			
American goldfinch *Spinus tristis*	6 (2)	7 (3)	1 (1)	195 (2)	11 (3)	36 (2)	18 (4)	24 (4)	25 (4)	53 (3)

Appendix V-04. (cont.)

Species	Transect Number (no. of censuses in parentheses)									
	1(7)	2(5)	3(5)	4(5)	5(6)	6(6)	7(6)	8(7)	9(7)	10(5)
rufous-sided towhee <u>Pipilo erythrophthalmus</u>	8 (3)	8 (4)	2 (2)	3 (2)	4 (3)	2 (2)	1 (1)	6 (2)	6 (2)	2 (4)
savannah sparrow <u>Passerculus sandwichensis</u>			x	6 (1)	22 (6)	15 (5)	20 (4)	11 (5)	x	5 (1)
grasshopper sparrow <u>Ammodramus savannarum</u>	x		x		2 (2)		x			
Henslow's sparrow <u>Ammodramus henslowii</u>										2 (1)
LeConte's sparrow <u>Ammospiza leconteii</u>					3 (1)	3 (2)				1 (1)
vesper sparrow <u>Pooecetes gramineus</u>	x		x	x	71 (3)	6 (2)	20 (3)	12 (2)		
lark sparrow <u>Chondestes grammacus</u>		x	x	2 (1)	21 (2)		2 (1)			
slate-colored junco <u>Junco hyemalis</u>	27 (3)	27 (3)	13 (3)	28 (2)	80 (4)	2 (1)	7 (4)	5 (1)	x	36 (1)
chipping sparrow <u>Spizella passerina</u>	4 (1)	x						2 (1)		
clay-colored sparrow <u>Spizella pallida</u>	x				1 (1)					
field sparrow <u>Spizella pusilla</u>	31 (3)	x		3 (1)	12 (5)	2 (3)		2 (2)		4 (3)
Harris' sparrow <u>Zonotrichia querula</u>	44 (2)	x	2 (1)	12 (2)	36 (2)					
white-crowned sparrow <u>Zonotrichia leucophrys</u>		x		1 (1)	1 (1)	12 (4)	3 (2)	x		

Appendix V-04. (cont.)

Species	Transect Number (no. of censuses in parentheses)									
	1(7)	2(5)	3(5)	4(5)	5(6)	6(6)	7(6)	8(7)	9(7)	10(5)
white-throated sparrow *Zonotrichia albicollis*	48 (4)	153 (5)	32 (3)	254 (3)	49 (6)	20 (5)	173 (6)	91 (7)	335 (6)	276 (4)
fox sparrow *Passerella iliaca*	18 (2)	1 (2)	21 (3)	10 (2)	1 (3)	20 (4)	16 (2)	1 (1)	3 (1)	3 (1)
Lincoln's sparrow *Melospiza lincolnii*	10 (4)	11 (4)	4 (2)	5 (2)	2 (3)	5 (3)	4 (2)	2 (1)		5 (2)
swamp sparrow *Melospiza georgiana*		1 (1)				24 (5)	1 (2)	9 (6)		11 (3)
song sparrow *Melospize melodia*	32 (3)	7 (3)	6 (2)	1 (2)	11 (3)	35 (4)	6 (4)	7 (4)		2 (2)
Smith's longspur *Calcarius pictus*					140 (1)					
Total of Maximum Individuals	1451	1251	1606	3787	2170	4145	1891	2316	1238	2095
Total Species All Censuses	101	70	101	97	81	81	105	120	86	101
Species Diversity[2]	5.4	4.5	5.1	3.3	3.6	2.8	4.7	5.2	4.9	4.2

Total Trinity River Census Species: 196 (plus 31 non-census species= 227).

[1] An "x" indicates the species was observed at that particular locality but not during a regular census.

[2] Computed using the Shannon-Wiener function(see text) and the maximum individual totals in the table as n_i's.

Appendix V-05
Creel Census - Trinity River Survey

Date:______________________ Time:______________________

Male:__________ Female:__________ No. of hours fished__________

Type of gear:__________________ Type of bait(s)__________________

No. of fishermen in party__________ Trinity Project Station No.__________

Temperature: Air:__________ Water:__________

Kind of fishing: Shore:________ Boat:________ Trolling:________ Casting:________

Other:______________________

Water Condition:______________________

List of Fishes Caught

Game Fishes	No.	Length (Range)	Est. Wt. (Range)	Remarks
1. Largemouth Black Bass				
2. Spotted Bass				
3. Bluegill				
4. Black Crappie				
5. White Crappie				
6. White Bass				
7. Channel Catfish				
8. Blue Catfish				
9. Other (specify)				
Rough Fishes				
10. Black Bullhead Catfish				
11. Yellow Bullhead Catfish				
12. Flathead Catfish				
13. Carp				
14. Smallmouth Buffalo				
15. Freshwater Drum				
16. Spotted Gar				
17. Longnose Gar				
18. Alligator Gar				
19. Other (specify)				

Appendix V-06
Fisheries Research Data Sheet

Coll. No. ____________

State or Country: ____________ Locality: ____________

____

County: ____________ Drainage: ____________

Water: ____________

Vegetation: ____________

____

Bottom: ____________ Temp: ________ Air: ________

Shore: ____________ Current: ____________

Distance from shore: ____________ Tide: ____________

Depth of capture: ____________ Depth of water: ____________

Method of capture: ____________

Collected by: ____________ Date: ____________

Orig. preserv.: ____________ Time: ____________

Turbidity (Jackson Turbidity Units): ____________

pH: ____________ Conductivity (mhos): ____________

COMMENTS:

Appendix V-07
FAMILY, SCIENTIFIC, AND COMMON NAMES OF FISHES REPORTED FROM THE TRINITY RIVER DRAINAGE SYSTEM

Petromyzontidae
- *Ichthyomyzon gagei* - southern brook lamprey

Carcharhinidae
- *Carcharhinus leucas* - bull shark

Dasyatidae
- *Dasyatis sabina* - Atlantic stingray

Acipenseridae
- *Scaphirhynchus platorynchus* - shovelnose sturgeon

Polyodontidae
- *Polyodon spathula* - paddlefish

Lepisosteidae
- *Lepisosteus oculatus* - spotted gar
- *Lepisosteus osseus* - longnose gar
- *Lepisosteus platostomus* - shortnose gar
- *Lepisosteus spatula* - alligator gar
- *L. spatula* x (presumably) *L. osseus* - hybrid gar

Amiidae
- *Amia calva* - bowfin

Elopidae
- *Elops saurus* - ladyfish

Anguillidae
- *Anguilla rostrata* - American eel

Ophichthidae
- *Myrophis punctatus* - speckled worm eel

Clupeidae
- *Alosa chrysochloris* - skipjack herring
- *Brevoortia patronus* - Gulf menhaden
- *Brevoortia gunteri* - finescale menhaden
- *Dorosoma cepedianum* - gizzard shad
- *Dorosoma petenense* - threadfin shad

Engraulidae
- *Anchoa mitchilli* - bay anchovy

Esocidae
- *Esox americanus vermiculatus* - grass pickerel

Characidae

Astyanax mexicanus - Mexican tetra

Cyprinidae

Campostoma anomalum - stoneroller
Carassius auratus - goldfish
Cyprinus carpio - carp
Hybognathus placitus - plains minnow
Hybognathus nuchalis - western silvery minnow
Notemigonus crysoleucas - golden shiner
Notropis amnis - pallid shiner
Notropis atherinoides - emerald shiner
Notropis atrocaudalis - blackspot shiner
Notropis buchanani - ghost shiner
Notropis fumeus - ribbon shiner
Notropis lutrensis - red shiner
Notropis potteri - chub shiner
Notropis sabinae - Sabine shiner
Notropis shumardi - silverband shiner
Notropis stramineus - sand shiner
Notropis texanus - weed shiner
Notropis umbratilis - redfin shiner
Notropis venustus - blacktail shiner
Notropis volucellus - mimic shiner
N. lutrensis x *N. venustus* - red x blacktail shiner hybrid
Opsopoedus emilae - pugnose minnow
Phenacobius mirabilis - suckermouth minnow
Pimephales promelas - fathead minnow
Pimephales vigilax - bullhead minnow
Semotilus atromaculatus - creek chub

Catostomidae

Carpiodes carpio - river carpsucker
Erimyzon oblongus - western creek chubsucker
Erimyzon sucetta - western lake chubsucker
Ictiobus bubalus - smallmouth buffalo
Ictiobus niger - black buffalo
Minytrema melanops - spotted sucker
Moxostoma congestum - gray redhorse
Moxostoma poecilurum - blacktail redhorse

Ictaluridae

Ictalurus furcatus - blue catfish
Ictalurus melas - black bullhead catfish
Ictalurus natalis - yellow bullhead catfish
Ictalurus punctatus - channel catfish
Noturus gyrinus - tadpole madtom
Noturus nocturnus - freckled madtom
Noturus flavus - stonecat
Pylodictis olivaris - flathead catfish

Ariidae

Arius felis - sea catfish

Aphredoderidae

Aphredoderus sayanus - pirate perch

Belonidae

Strongylura marina - Atlantic needlefish

Cyprinodontidae

Cyprinodon variegatus - sheepshead minnow
Fundulus chrysotus - golden topminnow
Fundulus grandis - Gulf killifish
Fundulus kansae - plains killifish
Fundulus nottii - starhead topminnow
Fundulus jenkinsi - saltmarsh topminnow
Fundulus pulvereus - bayou killifish
Fundulus notatus - blacksjripe topminnow
Fundulus olivaeeus - blackspotted topminnow
Adinia xenica - diamond killifish
Lucania parva - rainwater killifish

Poeciliidae

Gambusia affinis - western mosquitofish
Poecilia latipinna - sailfin molly

Atherinidae

Labidesthes sicculus - brook silverside
Membras martinica - rough silverside
Menidia audens - Mississippi silverside
Menidia beryllina - tidewater silverside

Syngnathidae

Syngnathus scovelli - Gulf pipefish

Percichthyidae

Morone chrysops - white bass
Morone saxatilis - striped bass
Morone mississippiensis - yellow bass

Centrarchidae

Centrarchus macropterus - flier
Chaenobryttus gulosus - warmouth
Ambloplites rupestris - rock bass
Lepomis auritus - redbreast sunfish
Lepomis cyanellus - green sunfish
Lepomis humilis - orangespotted sunfish
Lepomis macrochirus - bluegill
Lepomis marginatus - dollar sunfish
Lepomis megalotis - longear sunfish
Lepomis microlophus - redear sunfish

Lepomis punctatus - spotted sunfish
Lepomis symmetricus - bantam sunfish
L. cyanellus x *L. macrochirus* - green x bluegill sunfish hybrid
L. cyanellus x *L. microlophus* - green x redear sunfish hybrid
Micropterus punctulatus - spotted bass
Micropterus salmoides - largemouth bass
Pomoxis annularis - white crappie
Pomoxis nigromaculatus - black crappie

Elassomatidae

Elassoma zonatum - banded pygmy sunfish

Percidae

Stizostedion vitreum - walleye
Ammocrypta vivax - scaly sand darter
Etheostoma chlorosomum - bluntnose darter
Etheostoma gracile - slough darter
Etheostoma parvipinne - goldstripe darter
Etheostoma proeliare - cypress darter
Etheostoma spectabile - orangethroat darter
Percina caprodes - logperch
Percina sciera - dusky darter

Sparidae

Lagodon rhomboides - pinfish
Archosargus probatocephalus - sheepshead

Sciaenidae

Aplodinotus grunniens - freshwater drum
Cynoscion arenarius - sand seatrout
Cynoscion nebulosus - spotted seatrout
Leiostomus xanthurus - spot
Micropogon undulatus - Atlantic croaker
Pogonias cromis - black drum
Sciaenops ocellata - red drum

Cichlidae

Tilapia mossambica - Mozambique mouthbrooder

Mugilidae

Agonostomus monticola - mountain mullet
Mugil cephalus - striped mullet
Mugil curema - white mullet

Eleotridae

Dormitator maculatus - fat sleeper

Gobiidae

Gobionellus boleosoma - darter goby
Gobionellus shufeldti - freshwater goby
Gobiosoma bosci - naked goby

Bothidae

Citharichthys spilopterus - bay whiff
Paralichthys lethostigma - southern flounder

Soleidae

Achirus lineatus - lines sole
Trinectes maculatus - hogchoker

Cynoglossidae

Symphurus plagiusa - blackcheek tonguefish